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Представлены доклады конференции, посвященной использованию информационных технологий в гуманитарных исследованиях. Обсуждаются возможные пути развития цифровых гуманитарных наук (Digital Humanities) – одного из ключевых инновационных междисциплинарных направлений, которое объединяет методики и практики гуманитарных и вычислительных наук и характеризуется применением компьютерных методов в гуманитарных и социокультурных исследованиях.

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Thinking About the 'Mind' in Digital Humanities: Apple, Turing and Lovelace

Claire Clivaz, Swiss Institute of Bioinformatics (Lausanne, CH)

The mind is its own place, and in itself
Can make a Heaven of Hell, a Hell of Heaven.
John Milton, *Paradise Lost*, Book I, l. 233-234

Abstract

This article introduces an underestimated concept in Digital Humanities emergence history: the mind. Following Milad Doueihi suggestion, it revisits Alan Turing article (1950) as a milestone in the DH genealogy. The mind appears here as the key-concept, at stake in the confrontation of Turing with Ada Lovelace. The article demonstrates that the mind has to be considered in connection with the brain, the spirit and the 'unthought' (see Katherine Hayles and Nathalie Sarraute). The mind appears at the end of the inquiry as a place to keep together the physical brain and the poetical dimension, illustrated by the spirit. An example of the perception of the Apple logo, presented in Introduction and Conclusion, underlines that unthought elements are always present in a cultural context.

Keywords:

Mind, Alain Turing, gender, Apple logo, Digital Humanities history.

1. Introduction: What do you have in mind?

What do you have in mind when you say "apple"? Maybe the fruit you are eating regularly, but maybe also the Apple logo you see many times per day on a smartphone, computer, on your own things or in advertising. Indeed, if we google "Apple", the computing logo arrives before a real fruit, and ranks second in case of the free search engine *Qwanta*.

But in a surprising way, even if the Apple logo tends to be so clearly present in our culture, the historian Stephen Greenblatt does not devote a line to it in his detailed inquiry about the reception of the myth of Adam and Eve (Greenblatt, 2017). The fruit, and its interpretation as an "apple" is thus carefully discussed in his study. Greenblatt reminds us that the biblical text does not mention an "apple", but a fruit (16), present in the entire history of its reception (see especially 128, 129, 137), with interesting

interpretations such as the fatal fruit symbolizing private property as proposed by Reformer Gerrard Winstanley at the 17th century (195, 357). But one cannot find in this monograph a single word about the Apple computer entreprise and its logo with a bite, not even in a footnote.

Greenblatt explains, of course, that "over the centuries there have been innumerable interpretations of the story of Adam and Eve. Many of the most influential interpretations figure in this book. But it is impossible to convey the full richness, variety, cunning, and on occasion wildness of the vast archive that has accumulated and that continues to grow" (303). Nevertheless, the fact that the computing Apple did not find an evocation in this book remains a kind of a "cultural blind spot". Passing from the printed culture to the digital one, similar dichotomies between the form and the content happen regularly, as for example our way to speak about "dematerialization" for what is digital (Clivaz, 2016). I first introduced this phenomenon in my overview article on digital culture (Clivaz, 2012, 32). Each time it happens, it means an opportunity to go deeper in senses and significations.

That's the case for the Apple logo. This article will focus on the dimension that is at stake when one draws attention to the logo Apple symbol, leaving all the potential of this logo for other opportunities. The chosen point is the mind, and its impact in the emergence and definition of what one call digital humanities. Indeed the word "mind" is present in the very first version of the Apple logo, drawn by Ronald Gerald Wayne, the third co-founder of Apple, and briefly used for one year (Linzmayer, 2004, 6). This logo represents Isaac Newton, sitting down under an apple tree, with an apple in a circle of light and a verse of poet William Wordsworth: "Newton… a mind for ever voyaging through strange seas of thought, alone" (Wordsworth, 1805, l. 62–63). In quite a long poem of Wordsworth, the "spirit" is also evoked: "My spirit was up, my thoughts were full of hope" (Wordsworth, 1805, l. 18). And also what cannot or has not been thought: "I was obedient as a lute that waits upon the touches of the wind. *Unknown, unthought* of, yet I was most rich. I had a world about me, 'twas my own" (Wordsworth, 1805, l. 138–140; my italics).

The notion of the mind has been present since the beginning of the Apple adventure, in its first logo. One can also find it in Hebrew or German translations of the English expression 'digital humanities': *ruach digitalit* (digital spirit, in Hebrew); in German: "die digitalen Geisteswissenschaften"; one speaks also about "der digitale Geist". Each language considers this lexical field differently: French and German have only one word for "mind" and "spirit" (*esprit* and *Geist*). We face here a subtle linguistic point that could lead to further deep inquiries. In the framework of this article, we will begin to question the idea of the "mind" in the digital humanities, with our attention drawn to this concept by the first Apple logo.

In section 2, we will consider the necessity to adopt different points of view to visit the history of the emergence of the digital humanities, and propose to start with the famous

Alan Turing's article "Computing Machinery and Intelligence" (1950), focused on the mind. Section 3 will discuss this complicated text, keeping attention to the question of the mind. Meanwhile, we will consider the question of gender as an additional element, since Ada Lovelace plays an important role in Turing's article. After having enlarged the notion of mind by situating it in the triad mind-brain-spirit (section 4), the conclusion will come back to our starting point : the Apple logo.

2. Revisiting the emergence of the digital humanities

It is always useful to keep in mind the Plato's adage about "taking once again a fresh starting point suitable to the matter" (Plato, *Timaeus* 48b). It sounds particularly adequate when looking at diverse ways to choose a starting point to narrate the history of the digital humanities. Busa's visit to the IBM president in 1949 is often seen emblematic. In a recent article, Domenico Fiormonte affirms that there is no doubt that "Busa's undertaking founded the discipline of the Humanities Computing (although years later it was renamed Digital Humanities), but above all it laid the groundwork for a profound epistemological and cultural transformation" (Fiormonte, 2017, 30). But this starting point, even if evident for so many of us and for so many reasons, can be questioned. It is indeed situated in a specific context.

As I pointed in a previous article (Clivaz, 2017), Steven E. Jones' clever monograph about Busa demonstrates that "IBM's interests in 1949–1952 surely included shoring up post-war diplomatic relations with the Vatican, Italy, and Europe as a whole just at the advent of its World Trade Corporation" (Jones, 2016, 97). Conscious of this commercial context, Busa asks in a private letter written in 1960 if the cooperation between a businessman and a priest is blessed by God, and concludes yes, referring to an unidentified biblical verse. As Jones narrates:

> After discussing machinery and an upcoming conference in Tübingen, Father Busa closed by reporting that the work of the Center (CAAL) continued 'at full speed', and then posed a question : 'Do you think will God praise this co-operation of a high businessman with a priest ? I guess yes, for in the Bible He said that the business can, if we want, lead people to find Him each day'. A copy of the letter was sent to Paul Tasman with a typed note attached (probably written by an assistant to Mr. Watson) that joked, 'Mr. Tasman, As a Bible student I wonder where Father Busa finds such a statement ??? Kay M.' I leave the biblical question to the theologians, but the very fact that Busa posed the question (then answered it so quickly) indicates that he recognized in 1960 that it was debatable and might be controversial, the cooperation and alliance between the businessman and the priest, the technology corporation and the academic (and Jesuit) research project (Jones, 2016, 97).

This lengthy paragraph exactly outlines the controversies around a genealogical interpretation of Busa as the "DH father". Another important name in the pre-DHers generation is

Tito Orlandi, also an Italian. Julian Nyhan and Andrew Flinn, in their thoroughgoing inquiry in the DH oral history, have been able to shed light on informal but nevertheless decisive moments, such as this one : "Tito Orlandi recounts that his earliest memory of a computer dates to the 1950s when he saw an IBM machine in the window of an IBM shop in Milan. Around 1960, together with his PhD supervisor Ignazio Cazzaniga, he engaged in some brief exploratory work to see what role punched card technology might play in the making of a critical edition of *Augustine's City of God*" (Nyhan and Flinn, 2016, 75). In the reception history, Aquinas won over Augustine: in a similar way, Busa Aquinas electronic index has overcome Ellison electronic biblical index in the traditional memory of the DH emergence (Jones, 2016, 14). But it is time to open our memories to diverse remembrances.

Looking at progressive diversification of our perception of recent history, I was inspired by Milad Doueihi to consider Alan Turing's article "Computing Machinery and Intelligence" (1950). Indeed, the French thinker suggested to start DH history with Turing's article in 2014 (Doueihi, 2014, 8–9). Turing is at the same time a central scientific figure, and, socially speaking, a marginalized figure from the 1950s UK, calling to include the mind into consideration. Indeed, "Computing Machinery and Intelligence" starts in this way: "I propose to consider the question, 'Can machines think?'. This should begin with definitions of the meaning of the terms 'machine' and 'think'" (Turing, 1950, 433). Let's see what happens to this question.

3. Alan Turing, the mind and Ada Lovelace

This important article on computing and epistemology was published in *Mind*, a journal funded in 1876 with a high prestige as a philosophy journal from the 50s; it was progressively open to diverse subjects areas. By submitting his article to the journal, Turing gave it an impressive interdisciplinary impact, a strong focus that he will keep through all his life, working ultimately on patterns in biology.

The machine that he is analyzing is the "digital computer", an expression that sounds redundant to our ears, but not in the 50s. The first written trace we have of the English words 'digital' and 'computer' combined in a single phrase as opposed to an analogue computer, goes back to a 1942 scientific report by George Robert Stibitz (Williams, 1984, 310). In "Computing Machinery", Turing writes, assessing the impact of the digital computer: "the present interest in 'thinking machines' has been aroused by a particular kind of machine, usually called an 'electronic computer' or 'digital computer'. Following this suggestion we only permit digital computers to take part in our game" (Turing, 1950, 436). He describes an ideal digital computer as a 'human computer':

> The idea behind digital computers may be explained by saying that these machines are intended to carry out any operations which could be done by a human computer. The human computer is supposed to be following fixed rules; he has no authority to deviate

> from them in any detail. We may suppose that these rules are supplied in a book, which is altered whenever he is put on to a new job. He has also an unlimited supply of paper on which he does his calculations. He may also do his multiplications and additions on a 'desk machine', but this is not important (Turing, 1950, 436).

To open the possibility for this machine – described as a human computer – to really *think*, Turing explains that a random element should be added to it (438). Random element and 'free will' are the necessary elements to go in the direction of letting it 'think'. It is his way to counter the strongest of the six objections towards the idea that a machine could think. The strongest objection was raised by Ada Lovelace (Ambramson, 2008, 157). As Turing summarizes it: "Our most detailed information of Babbage's Analytical Engine comes from a memoir by Lady Lovelace (1842). In it she states, 'The Analytical Engine has no pretensions to *originate* anything. It can do *whatever we know how to order* it to perform' (her italics)" (Turing, 1950, 447). Valeria Aurora pointed out, in defense of Ada Lovelace, that Turing misread her, while she was defending the same point of view as Turing (Aurora, 2016, 232–233). As far as I have been able to verify it, Turing does not seem to refer to Lovelace's work itself but to Douglas Hartree's work (Turing, 1951, 2). Turing wrestles with what he considers "Lovelace's objection". To overcome this point, he develops two main arguments, and the first one is the random element idea, which leads him to speaking about digital computers in an anthropomorphic fashion (see sentence in italics):

> A better variant of the objection says that a machine can never 'take us by surprise'. This statement is a more direct challenge and can be met directly. *Machines take me by surprise with great frequency.* This is largely because I do not do sufficient calculation to decide what to expect them to do, or rather because, although I do a calculation, I do it in a hurried, slipshod fashion, taking risks. (Turing, 1950, 448)

To concede or recognize that the machine has the possibility to *originate* something, is a surprise for the human, Turing has to put in balance the moments where his own human mind is somehow inefficient : "because I do not do sufficient calculation… or I do it in a hurried fashion, taking risks". This breaking point in Turing's argumentation is fascinating : it recognizes an implicit concurrency between the human mind and computational potential, something that has become today explicit and everyday is growing up. In the fifties, Turing is already hoping for our present computing developments. Coming back at the end of the text to Lovelace's objection – the one which *means* the most to him –, he gives the future as the horizon to give her a full answer one day: "Let us return for a moment to Lady Lovelace's objection, which stated that the machine can only do what we tell it to do (452). […] The only really satisfactory support that can be given for the view expressed will be that provided by waiting for the end of the century and then doing the experiment described" (Turing, 1950, 455).

The second argument that Turing opposes to Lovelace objection's is the brain, or a pure mechanical perception of the mind, that he simply put in as synonymous of the mind :

"In considering the functions *of the mind or the brain*, we find certain operations which we can explain in purely mechanical terms. This we say does not correspond to the real mind: it is a sort of skin, which we must strip off if we are to find the real mind. But then in what remains we find a further skin to be stripped off, and so on. Proceeding in this way do we ever come to the "real" mind, or do we eventually come to the skin, which has nothing in it? In the latter case the whole mind is mechanical" (Turing, 1950, 454–455).

Should we speak here about Turing's demystification of an old Western concept of 'mind'? Almost seventy years later, it has at last become evident that 'brain' is a word really more challenging for scholars than 'mind', especially if we consider the huge European flagship *Humain Brain Project*. Turing's proposal could, after all, sound simpler compared to the one used today: let's consider simply the skin, as it is, without other dimensions implied. Starting on this base, making the digital computer similar to a mechanical human brain does not sound so impossible, if we add the random element recommended by Turing.

I do not claim I would like to oppose this point of view. My attempt is to emphasize an important missing word or concept in Turing's essay about the mind: the spirit. As we have seen, English separates the meanings unified in similar words in German or French. It is not surprising that Turing does not consider this concept in his article, since his favorite option, to resist the main objection by Lovelace, is to compare the mind to the physical brain. What is missing in a text seems to matter. Section 2 introduced the spirit in Wordsworth's poem: "My spirit was up, my thoughts were full of hope". In the Judeo-Christian tradition, the spirit has a long gender pre-history: it is female in Hebrew and in the biblical Old Testament or Hebrew Bible (*rouach*); it is neutral in Greek and in the New Testament of the Christian Bible (*pneuma*). Only Latin turned it into a male word (*spiritus*). The spirit represents a flexible and open element in the Christian trinity, or even a female one in the Hebrew Bible.

If Turing does not speak about the spirit, it is worth to notice that genders are present in this text, as aside element. At the very beginning, he describes people playing an 'imitation game' in this way: "It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex" (Turing, 1950, 433). Further, he assumes that "the best strategy is to try to provide answers that would naturally be given by a man. [...] One might for instance insist that the team of engineers should be all of one sex, but this would not really be satisfactory, for it is probably possible to rear a complete individual from a single cell of the skin (say) of a man" (435–436). In context of the 50s, such a point of view in an academic text is surely common and understandable. Nevertheless, the person who presents a stronger objection to Turing is Ada Lovelace, a woman. A full gender reading of Turing's article is something that future scholars will have to do.

One can go a step further by pointing to the absence of the notion of "unthought", expressed in Wordsworth's poem: "I was obedient as a lute that waits upon the

touches of the wind. Unknown, unthought of, yet I was most rich. I had a world about me, 'twas my own " (Wordsworth, 1805, l. 138–140). This notion is taking an important place in the DH landscape and it is outlined in the last book of Katherine Hayles, *Unthought. The power of the cognitive nonconscious* (2017). Back in 2012, she was already describing the meaning of the "unthought" using this example : "A woman who worked on Morse code receiving [...] during World War II reported that after her intense experiences there, she heard Morse code everywhere – in traffic noise, bird songs, and other ambient sounds – *with her mind automatically forming the words to which the sounds putatively corresponded*. Although no scientific data exist on the changes sound receiving made in neural functioning, we may reasonably infer that it brought about long-lasting changes in brain activation patterns, as this anecdote suggests" (Hayles, 2012, 127–128; my italics).

Is such an example taking us back from the "spirit" to the brain, as described by Turing? We stand here in fact at a subtle crossroad between the nonconscious, the unthought, the materiality and the poetics. We realize it by reading a poetical description of the unthought, written by Nathalie Sarraute, a French author, born in Ivanovo-Voznessensk in 1900, and dead in Paris in 1999. In her book *Tropism*, she describes in a narrative way how we are affected by the "unthought"; she describes the unconscious movements of the brain, of our emotions: "These movements, of which we are hardly cognizant, slip through us on the frontiers of consciousness in the form of indefinable, extremely rapid sensations. They hide behind our gestures, beneath the words we speak and the feelings we manifest, all of which we are aware of experiencing, and are able to define. They seemed, and still seem to me to constitute the secret source of our existence, in what might be called its nascent state" (Sarraute, *The Age of Suspicion*, 1956; engl. Tribout-Joseph, 2008, 13). Sarraute comments here on the literary and poetic effect she developed in *Tropismes* (first published in 1931).

It is probably crucial to notice that Sarraute uses a literary example in 1931 and 1956 to demonstrate what we are now beginning to describe physically as a phenomenon happening in our brain. These two aspects should not be separated. The 'mind' is eminently at stake when we enact our capacity to relate the poetic dimension and physical brain in order to represent the reality to ourselves. The 'spirit', beyond its theological flavor, belongs to the poetical sphere, and triggers a long tradition of our capacity to express the 'unthought', as shown in this passage from Paul of Tarsus: "In the same way, the Spirit helps us in our weakness. We do not know what we ought to pray for, but the Spirit himself intercedes for us through wordless groans" (Rm 8,26). Wordless groans of the spirit and unthought of the mind lead to situate our perception of the brain in a cultural framework.

In summary, I would say that the mind that becomes conscious of its debt to the brain stays in touch with its spiritual part, as long as it produces poetical expressions,

seeking the 'unthought'. We can notice that placing the 'unthought' below the rational line of argumentation, Turing's article also shows implicit dimensions, such as the one of gender. To follow Milad Doueihi's suggestion – to begin a DH history with Turing's article – means to give voice to Turing and Lovelace, a man and a woman, two people who have not been at the center of the stage in their contemporary societies for gender or sexual orientation issues. It is a fascinating place to start a DH history and reconfigure the notion of 'mind' from Turing's 'imitation game' to the cognitive unthought introduced by Hayles. If now we come back to our starting question – the Apple logo –, we face Turing' questions and gender questions in the quest for the origin of the logo that is so emblematic of the digital culture.

4. Conclusion : the Apple logo

Where does the Apple logo come from? What does a bitten apple mean, first colored, then in grey or metal color? Such a question is raised in the academic movie *Le modèle Turing* produced by Catherine Bernstein in 2012. The French philosopher Michel Serres claims in the film that the bitten apple in the logo refers to the dramatic story about Turing's death. Turing is supposed to have committed suicide by eating a poisoned apple: "ce logo, c'est toujours la pomme de Turing, il n'y a aucun doute là-dessus"; "this logo is always the Turing apple, there is no doubt about that" (Bernstein, 2012, minute 26, 21–24). Before that, Serres explains that he agrees with a dramatic story about Turing's sucide : "I belive it is true" (Bernstein, 2012, minute 25, 18–27).

I am much obliged to the Pommier publisher for an opportunity to ask Michel Serres if he had any evidence confirming the origin of the Apple logo. In fact, it was just an oral story heard from several colleagues in the Silicon Valley. Ian Watson (2012) clarifies the story. He explains that Stephen Fry, a BBC presenter, speaks in a BBC program about Steve Jobs, Apple founder, denying the fact that the Turing apple was the origin for the logo: "It isn't true, but God we wish it were!". Watson comments: "Whenever I see the Apple logo I remember Turing, for without his discoveries Apple's products would not exist" (Watson, 2012, 85). Additional evidence on the topic was produced by Wozniak, Apple co-founder who said in 2004 that he never asked Jobs about the origin of the apple choice: "Steve Jobs had just come back from one of his trips and we were driving along he said 'I've got a great name: Apple Computer'. Maybe he worked in apple trees. I didn't even ask. Maybe it had some other meaning to him" (Linzmayer, 2004, 5). There is nothing on Turing's story Linzmayer's book written in 2004. Apparently, the phrase emerged later.

The link to Turing did not relate to the original choice of an apple in the Apple logo. Indeed, we have seen the Newton apple – without a bite – in the very first version of the logo drawn by Wayne, in section 1. According to graphic designer Rob Janoff, "the 'bite' in the Apple logo was originally implemented so that people would know that it represented an apple, and not a cherry tomato", as a second step (Think Marketing, 2012).

Nevertheless, Watson comment shows that the "Turing interpretation" of the Apple logo is now strongly embedded as an interpretation effect in the perception of the logo history. It will surely be successful, since the LGTB rights have now really progressed: the interpretation is emblematic in this case.

In summary, one can say that the choice of an apple, combined with a powerful verse from Wordsworth, was very successful for Apple Compagny. As Jean-Louis Gassée, former Apple executive and founder of BeOS, explains: "One of the deep mysteries to me is our logo, the symbol of lust and knowledge, bitten into, all crossed with the colors of the rainbow in the wrong order. You couldn't dream a more appropriate logo: lust, knowledge, hope and anarchy" (Think Marketing, 2012). The apple of Adam and Eve already had all these symbolic dimensions. It remains an ambiguous fruit that we contemplate about each time we open our Apple computer or use our iPhone, a kind of digital *pharmakon*. Corrupted or safe, entire or bitten, poisoned or tasty, the apple is the same fruit. Humans transform it according to their responsibility and sense of duty. It was the opinion of Augustin, a philosopher and Christian writer, from the 5th century: "The apples of the fatal tree were the same kind as the apples Adam and Eve had already found to be harmless on other trees" (Augustin, *On Genesis*; quoted by Greenblatt, 2017, 343, footnote 113). Our minds have a difficult duty to distinguish between them.

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Visual representations as models of the past

Øyvind Eide

Introduction

In this paper some examples of documentation activities connected to an archaeological excavation which took place in 1904 will be analysed. The focus will be a set of objects connected to the so-called Oseberg ship, contextualised within the study of modelling practices in the humanities (Ciula and Marras 2016; Ciula and Eide 2017). As the objects take actively part in the relational process of several modelling efforts, its identity and properties are affected by the specificity of each modelling process, modified by the context of production and use of modelling processes. The insights that models bring around a specific phenomena can be of different nature: from practical evidence for how an excavation site was organised to evidence based scholarly knowledge about the Viking societies in Scandinavia and their production and use of material culture. The aim of this study is to use the documentation material as a case study which shows in practice how different modelling approaches operate in relation both to their contexts of production and use as well as in relation to each other.

Finding Oseberg

In August 1903 the farmer Oskar Rom visited Professor Gabriel Gustafson in Oslo. While digging in a burial mound on his property he had found parts of an old ship. Professor Gustafson immediately arranged to visit the farm Lille Oseberg a few hours' travel outside Oslo and started his investigations. The excavations themselves took place in the summer of 1904 and sparked significant public interest, not the least due to the national sentiment at this specific time in history – Norway became independent from Sweden in 1905. Professor Gustafson was not only director of the Oslo museum for antiquities but also Swedish. The Oseberg excavation had far-reaching consequences and was important in the process that led to the establishment of a Norwegian law for protection of cultural heritage[1].

The Oseberg ship was in fact the grave of two women who died in 834 CE. Who they were and how they were related remains a mystery. They were equipped with a significant treasure for their travel to the afterland: not only a highly decorated ship made for 30

[1] The law was passed in 1905 under the title "Law on conservation and protection of remains from the past" (Norge 1905. All translations by the author).

oarsmen but also animals (horses, dogs, and cows), clothes including silk, equipment of various types, sleights, a cart, beds, and tents. The ship itself was broken to pieces but most of the wood still remained – as of today more than 90% of the wood in the reconstructed ship is original. The preparation and restoration of the ship and the other major finds lasted for more than 20 years. The excavation itself took place in less than three months; yet it was an impressively professional scholarly undertaking for its time, as will be discussed further below.

Physical reconstruction as a modelling process

While the excavation and its advanced level of documentation give clear indications of the form of the Oseberg ship, it was still not a straightforward process to re-create a ship based on the state the remains were in in 1904. "To reconstruct is here a process, that through re-building and construction leads to a reconstruction, which is a term for the final product"[1]. While this specific ship is closer to the original than what is often the case in comparable reconstructions due to the high percentage of original wood it is still not correct to call it a restoration. Paasche calls for use of the word pair reconstruction/construction. Such a reconstruction is similar to a modelling process in that the reconstruction was based on implicit and explicit models of how ships were constructed in The Viking Age held by the experts involved in the process. So while the reconstruction is a process of translation from artefact remains to artefact it also includes aspects of a process of translation from model to artefact (Eide and Eide, 2016).

This is common for many of the modelling processes we study. They are processes of modelling, but not only one type of modelling – other perspectives highlight other aspects. The process does not include distinguishable modelling and reconstruction parts, both aspects are rather present at the same time. The distinction is analytical. Indeed, one of the important understandings, namely, that the ship was fit for coastal sailing only and would not handle open sea, that it was made for ceremonial purposes only, may be based more on how the reconstruction was done than the actual evidence found during the excavation. We will come back to how later modelling experiments (simulations) strengthened another theory that was originally based on dendrochronology[2], namely, that the ship was built in Western Norway and sailed the open sea around the coast to the Oslo fjord.

This is not the place to discuss changes in scholarly paradigms in any detail. It is still useful to make the general point that in all studies of cultures we face an unsolvable paradox: in order to do sound scholarly work on a culture we need to know as much as

[1] "Å rekonstruere er her en prosess, som gjennom gjenoppbygging og konstruksjon fører fram til en rekonstruksjon som er betegnelse på det ferdige produkt" (Paasche 2010: 62).

[2] Dendrochronology is a method through which the growth rings in wood is used to place the felling of the trees the wood is take from, at best, to a specific year in a specific geographical area.

possible about it, but knowing a culture there is a risk that we adjust new information to fit our previously established views. Professor Gustafson worked on the excavation with a large team, both at the excavation site and in the museum taking care of the findings and the documentation coming in. They would all have more or less scholarly and experience based models of what they were unearthing. Many of them would know boats of a comparable type as the Oseberg ship, as the Norwegian boat building tradition in the nineteenth century was a continuation of medieval traditions, although it was a long time since these techniques had been used for anything of the size of a Viking ship built for open sea.

Such paradoxes are solved in partly different ways in different disciplines. In archaeology this problem is intensified by the fact that the objects of study in many cases are taken out of context, sometimes even damaged or destroyed. Nobody can ever investigate the site of the Oseberg ship again seeing anything comparable to what the team saw in the summer months of 1904 – the site as it was is gone forever. The only solution is to record as much as possible of what is seen in order to create a level of reproducibility, given limitations in resources, methods, and skills.

Plans, figures, geometry – and text

Fig. 1 shows the Oseberg ship as it is usually seen. Its visual form, together with those of a few other ships, has embodied the icon of the Viking age for generations of fascinated visitors to the museums. While the period from 800 to 1050 was multi faceted and trade was an important part of the interaction between the Nordic Countries and other parts of Europe, the Middle East and Central Asia, the act of going Viking was violent. Yet, the beauty of the Viking ships, the efficiency, flexibility, and forcefulness of their lines show a highly sophisticated boat building tradition which in important ways was far beyond anything made by their opponents in the rest of Europe, the Middle East, and Central Asia. Those lines form part of a collective image of the Viking age.

Yet, by looking at Fig. 2 one can clearly see that what was found during the Oseberg excavation gave quite a different impression. This is nothing new, of course. The fact that the ship one can see today is a reconstruction is well known, as is the state of the object when it was found. Yet, if an image says more than a thousand words then an object says more than a thousand images. Most of us believe what we see. And indeed, as pointed out above, most of the wood in the ship comes from the ship found during the excavation. It is old. It is real.

The stories told about Oseberg say much more than the objects in the museum. The ship as a physical form is but one aspect of the materiality of those stories. By studying the documentation from the excavation one can not only see where things were but also deduce many aspects of what happened at the time of the burial. The artefacts and

Fig. 1. The Oseberg ship in the Viking Ship Museum. The Museum of Cultural History, University of Oslo / Eirik Irgens Johnsen

Fig. 2. Excavation of the Oseberg ship in 1904. Museum of Cultural History, University of Oslo / Olaf Væring

the context are used to create models of the past. The excavation also created models at other levels. One level entails the adjustments of mental models already held by the excavators. Further to that, all available recording media were used to document what was found. Indeed, creating lasting models is a process of mediation. All models, and parts of models, are media products. They are in themselves, separately, models, resulting from modelling processes. They are also the building blocks of larger, more complex models. The models of the whole site. The models of the events taking part in the 9th century. The models of the Viking society.

Oseberg is just one grave, with two dead persons, a small sample indeed. However, just the fact that these two are women has contributed in shaping our models of what the Scandinavian societies at the time were like. Oseberg took part in forming both the self understanding and external views on Scandinavia, also in smaller and more mundane ways, such as the use of Oseberg motives on stamps. The models of the finds and the theories of the past societies became models for a general view on the Viking society, models with significant political power. The political potential was not only taken out in the years around independence in 1905 but has also been used by quite different ideologies including the nazi government during the German occupation in 1940–45.

The main means of visual documentation at the time were black and white photography, paintings, drawings, and sketches. The textual is present partly as additional information on the drawings, partly as longer texts. Often these media forms complement each other. Fig. 3 and 4 show a photography and a sketch of the remains of a horse, illustrating clearly how the information is different and complementary. It also shows an example of how the sketches often include textual information. All these three media types establish iconic relationships of similarity between themselves and the reality of the

Fig. 3. The Museum of Cultural History, University of Oslo / Ill 1b. CfO0069/C55000_1. Horse carcasses port in the bow of the ship

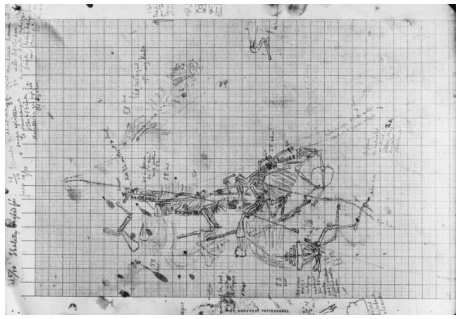

Fig. 4. The Museum of Cultural History, University of Oslo / Ill 1a. CfO0184/O1904_ hesteskjelett. Copy of plan over skeletons (horse) port in the bow of the ship

excavation pit but it is done in different ways (Ciula and Eide 2017). The photographies have image like iconic relationships established through the indexical process of analogue photography, showing also some structural relationships. The sketches and drawings also establish image like relationships to the modelled reality, but goes further in expressing also structural similarity. The textual annotations clarify structural and context relationships through the use of the "semiotic freedom" of the written language.

While some types of media objects, such as the results of laser scans, are usually seen as models, photograps and sketches are often described in other words. But such graphical forms in the context of archaeological documentation are clearly models (Nakoinz forthcoming). By observing a diagram one can establish new knowledge through iconographic reasoning (Ljungberg forthcoming). The concept of modelling describes a process in which media products, such as images or drawings, are created and a model relationship between the media product and something external is established. The photograph and the drawing are models of the remains of the horse. However, the two media types, similar as they are, still opens up for different types of use, they afford different types of engagement. The photograph gives a clearer image of how things looked during the excavation, where the drawing clarifies the elements of the skeleton and how they relate both to the anatomy of the horse in general and the specific object in the museum. The materiality of the documents is also important: once scanned and available on a computer types of deformance such as zooming and filtering becomes available in a different way from how comparable operations can be performed on a film or a paper copy. We will see below how other types of models afford yet other types of engagement.

The process of creating these documents can also be described as a mediation process where the process establishes a media product based on a human created artefact, namely, the killed horse (Eide 2015: 195–8)[1]. These are two ways to describe the same process, coming out of two different scholarly traditions. Thus, both modelling and mediation are connected to the same process, the difference between them is our perspective on and understanding of the process, rather than the process itself[2].

The process of reconstructing the ships and the other objects found during the excavation were not processes of direct causality. There were no manuals in the graves for how to build the ships – it was neither a Lego project nor an IKEA set of instructions. The pre-knowledge, the mental models held from before 1904, were parts of the basis for the reconstruction. However, the semiotically rich models created as parts of the excavation made what could have been a highly speculative activity into a scholarly evidence-based process. Not a perfect one – as we point out repeatedly aspects of the

[1] "Human created" here means that humans killed the horse in a cultural setting. It does not imply that no other forces took part in the process of transforming the dead horse into what was found in 1904.

[2] This is a simplification as our understanding is also an undividable part of such processes. However, this would opens for a complexity which it would be beside the point to explore here.

reconstructions are questionable – but still one based on solid scholarly evidence. A large number of mediated models were there, and are still there for those who want to understand better the context of the Oseberg excavation, the objects found there, and the history of the restorations and reconstructions.

Prescriptive modelling

Det Norske Veritas is a classification, verification, and risk assessment company with a strong focus on shipping.[1] This company was hired to write a report evaluating the sustainability of the Oseberg ship. The work included assessment of the current situation, evaluation of the support pillars and possible fracture in the wood, and proposals for how to move the ship which, at the time of the writing of the report in 2005, was under discussion (DNV 2005: 8).

The strength model of the ship they developed is based on input from different sources, including 3D scans, manual survey of damage, and testing of material properties. The strength model is also called a calculation model, which highlights it dynamic aspects. This model is created as an element model consisting of a large number of elements with independent connections between them and is used to evaluate the current stress situation and make prescriptions for the future, both linked to better support and to a possible moving of the ship (ibid.). The main aim is to create a model which can not only prescribe what will happen, but also decrease the risk of negative events if the ship is moved:

> The calculation model has been used to analyse a few examples of accidents and the extent of undesired events in connection with a potential move. It is demonstrated how such calculations can be used to establish requirements about handling the ship, supporting the ship and dimensioning the transport frame (ibid: 3).

The report aims at reducing future risks also for the ship in its current location through the analysis of possible extensions of the support frames. So we see an example of prescriptive modelling, but not to test hypotheses (e.g., how much a Viking ship can take before it breaks) but rather to influence the future. Through presenting decision makers with hypothetical scenario based on the strength model of the ship they are expected to make better decisions, hopefully combining their aims (keeping the ship available to the public, possibly moving it) with a highest possible likelihood that it is not damaged. Modelling in this sense is similar in aims to climate modelling and some of the modelling found in political science and conflict studies. The model does not strictly speaking give any information about the future, but can be used for simulated hypothesis testing,

[1] In 2013 Veritas merged with Germanischer Lloyd, forming the new company DNV GL. As we describe earlier events we will refer to the company as "Veritas".

evaluating the consequences of different assumptions as to the degradation of the material.

The level of detail in the model is in line with the accuracy of the collected data. The model itself is constructed as elements connected to neighbouring elements, all of them having material properties as we saw above. The geometry structuring the model comes from the digital results of the 3D scanning of the ship. Yet, the object being modelled in the strength model is not just the ship. The materiality of the model is a flexible deformable computer stored object. The active use in the simulations is indeed intimately connected to the ship but the main purpose is to create models of future events. To clarify how the dynamic aspects work some more detail will be given.

For the moving of the ship, two different types of unwanted events were identified. First, accidents that should not happen and can be prevented through strict procedures. Second, unwanted events which are to some extent inevitable, as one has to handle the ship in order to move it. The aim is to plan for avoiding the first type and minimise the consequences of the second type. The concrete examples of events described are not necessarily the most likely ones to happen; the aim is rather to show how the model can be used to provide realistic hypotheses for changes in tension. This includes identifying how the likelihood for breaches is changed through changing parameters such as support or level of strain. Thus, this work provides tools for further simulations rather than "OK or not" checklists. The calculation of the likelihood for a breach is called "Fiction" (ibid: 34) not because it is not well founded but because the result is rather a reference point than an absolute value[1].

Although truthfulness is an important part of modelling, all models are to be evaluated based on their usefulness – never being identical to the modelled object they are never true in a strict sense. Thus, given no catastrophe happens, the quality of the Veritas modelling can only be truly assessed decades from now, as the real assessment of climate models also has to be made in the future. However, both types of modelling still have quality assurance methods. The Veritas team was able to make a number of verifications through using different methods and through references to previous scholarly work on wood material preservation, cf. the matrix of the relationship between tension and bending (ibid: C-1).

The report explains in details how one should act in order to safeguard the ships, but it also explains the background for the advice – to show how they are evidence based but also to show the uncertainty of the results. It is argued repeatedly that the results are not accurate, but also, how they are conservative, thus, they work as a "best before" labelling on food – you may be fine even if going beyond but staying within you are sure, unless something totally unexpected happens, such as something heavy falling onto the ship.

[1] Cf. how the concept of fiction in scientific models is used, see e.g. Suarez (2009).

New evidence and scale models

The reconstruction of the ship was done at a specific point in time according to the knowledge and evidence available at the time. What we see as the exhibited ship is based on one interpretation of what was found in the grave. We have seen above that it is a scholarly well founded interpretation. However, other well founded reconstructions could also have been possible.

Traditionally the ship was assumed to be fit only for local travel in the Oslo fjord, and not able to sail the open seas. This assumption has partly been based on the assumed sailing capabilities of the ship as it can be seen in the museum. The history of the ship, including its place of construction, was established based on available evidence, and the historical modelling of the burial events and their political context has been based on that. Then, in the 1990s, dendrochronological studies showed that the grave was constructed in 834, and that the burial chamber in the Oseberg ship was built from regional oak. The same type of wood was used to repair the ship. The ship itself, however, was built in Western Norway (Bonde and Stylegar 2009).

Bonde and Stylegar use the new evidence and understanding around the production of the ship to re-contextualise the burial in political and social settings, suggesting new interpretations of written continental sources and the relationship between the areas in today's Norway and the rulers of what is now Denmark. Here we will explore another consequence of the dendrochronological results. Given this new evidence the ship itself, as it can be seen in the museum, could be (and in fact is in the process of being) questioned. We remember that the reconstruction happened based on evidence – but as in all such situations, on a limited set of evidence with a certain room for possible interpretations, a "room of possibilities" (Eide 2015: 178–180). The question has arisen between curators and scholars if the ship could have been different within a reasonable room of possibilities? Supported by the building of scale models, recent research points towards a positive answer.

Experiments conducted in 2008 on a 1:10 scale model of the ship in a ship modelling tank indicate that it may have had quite good sailing abilities (Lundeby 2014: 3–36). Building replica of Viking ships from wood is an extremely time and money consuming process. In addition it is highly skilled work – just making planks using an axe rather than a saw is quite difficult and takes considerable training. A hand made scale model can to some extent replace full scale reconstructions. In the modelling tank experiments only small modifications to the scale models led to quite different results, supporting the possibility of significantly higher stability at higher speed and under the stress of higher waves[1]. Our aim here is not to give evidence for one model rather than the other,

[1] "Osebergskipet langt mere sjødyktig enn antatt." Stiftelsen Nytt Osebergskip, news item from July 1 2008. https://tinyurl.com/yc5lz6do (accessed 2018-05-02).

but rather to show how modelling processes based on quite different methodologies – archaeological, historical, and engineering – work together to create and support new hypotheses; not based on newly excavated material but based on new interpretations of existing artefacts in the museums.

While all the methodologies described above have their limitations they can still help researchers in evaluation their hypotheses, bringing the research further. It can also, through testing many different versions of the model, prepare for the construction of a physical full scale hand made replica by clarifying what the most interesting way to build it would be. The news item referred to in footnote 17 above is indeed taken from the webpage of a project aiming for the construction of a new Viking ship. Scale models can add a level of interactivity which can give researchers, students, and the interested public a deeper understanding of the ships by showing how they could have been different and how changing parameters would change them. It can also be used in simulation experiments to gain new scholarly knowledge of what is through exploring what could have been.

Conclusion

In this paper a number of different models have been analysed. Their materialities and modalities are quite different, from flat image surfaces and scans to manipulable physical and virtual 3D models. While all these models in various ways are spatial they are also actively used in time. They represent in their different ways both objects and processes. Their affordances and use vary based on their different materialities. An image or a sketch in its digitised computer based version can be zoomed, turned around, and manipulated by more advanced image manipulation methods such as filtering. A physical scale model has physical attributes that can be tested in an environment, such as the ship model in a water tank. Similarly a computer based 3D model can be put into a virtual environment and various hypothetical situations can be simulated.

Many of the oldest models used in this case study were created for a purpose more or less similar to what we use them for today. Photographs and sketches from the excavation were digitised more recently and through that process have changed material interface, but they are generally used to understand and contextualise aspects of the excavation and the objects found in similar ways as their originally intended use. This is not the case for the dendrochronological and C14 analyses. The wood was stored in the museum without modern dating methods in mind. However, it is an aspect of museology that objects may be exposed to novel methods in the future, so they should be preserved also when no clear scholarly or pedagogical use can be seen.

Much of the modelling practice we have seen in this article is directly linked to physical objects and replica thereof. The pictures and drawings were of the remains of the horse

and other objects from the excavation. We looked at different models of the Oseberg ship; again images, also digital 3D models and replica. Even the stress model, abstract as it may be, is a model representing the object.

We have also looked at some models that are linked to more abstract features. We did discuss the general Viking ship concepts held by those involved in the excavation, and we have seen how models of Viking society can be modified by new modelling techniques. Once one creates a specific scholarly/scientific model this model puts various degrees of limitations on its possible use area. The model affords certain types of use.

However, it is not enough to claim that models are models of objects. There is no straight forward representation taking place in the modelling activities we have seen. It is rather a complex activity of re-thinking our conceptualisation of the objects and their role and meaning in historical as well as modern times. In this perspective we see clearly how the models also express the world view of their creators in creative tension with what the objects can tell us. This is clearly shown in the examples of models changing the understanding of the objects. The objects themselves are not changed, there is nothing happening in the objects suddenly forcing us to make new models. The change is in our academic and intellectual and practical world. We think in new ways, and we develop new methods. This calls for the possibility of new models that can change, often in detail but sometimes also in larger scale, influencing our understanding of the past and the present.

In this sense models are not only the physical or virtual objects we interact with. Also the processes we create as replica of processes in the past. Such performances are part of modelling practice, they are models. The process of sailing a model ship in a tank is a model of the process of sailing a Viking ship more than 1000 years ago. In the icon based model of modelling a similarity can exist between processes, not only between physical or virtual objects. In our pragmatic iconographic thinking about models this aspect is not yet explored in the depth it deserves. Deepening our understanding of the dynamism of modelling linked to historical and model processes is an important target for future research.

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Personality Traits and Typology of Drug Consumers: Data Analysis

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Abstract

We present analysis of correlations of use of different substances and description of the groups of drugs with correlated use (correlation pleiades). We found significant differences of personality profiles for users of different drugs. This is explicitly demonstrated for bensodiazepines, ecstasy, and heroin.

Introduction

In this paper, we present some results of the interdisciplinary project "*Personality traits and drug consumption*". More detailed report will be published in Springer (Fehrman et al., 2018). Some intermediate reports are available online (Fehrman et al., 2015), presented at the Conference of International Federation of Classification Societies 2015 (IFCS2015, Bologna, Italy) (Fehrman et al., 2017), European Conference on Data Analysis 2015 (ECDA2015, Colchester, UK), and Digital Humanities 2017 (Krasnoyarsk, Russia).

The practical importance of the problem of evaluating an individual's risk of consuming and/or abusing drugs cannot be underestimated. One might well ask how this risk depends

on a universe of possible factors (Hawkins et al., 1992)? The linking of personality traits to risk of substance use disorder is a classical problem (Kotov et al., 2010).

The data set we collected contains information on the consumption of 18 central nervous system psychoactive drugs, by 2051 respondents (after cleaning, 1885 participants remained, male/female = 943/942). The database is available online (Fehrman & Egan, 2016, Fehrman et al., 2016).

Personality traits

Nowadays, after many years of research and development, psychologists have largely agreed that the personality traits of the modern Five Factor Model (FFM) constitutes the most comprehensive and adaptable system for understanding human individual differences (Costa & MacCrae, 1992, McCrae & Costa, 2004). The FFM comprises Neuroticism (N), Extraversion (E), Openness to Experience (O), Agreeableness (A), and Conscientiousness (C).

The five traits can be summarized as:
N *Neuroticism* is a long-term tendency to experience negative emotions such as nervousness, tension, anxiety and depression (associated adjectives (McCrae & John, 1992): anxious, self-pitying, tense, touchy, unstable, and worrying);
E *Extraversion* is manifested in outgoing, warm, active, assertive, talkative, cheerful characters, often in search of stimulation (associated adjectives: active, assertive, energetic, enthusiastic, outgoing, and talkative);
O *Openness to experience* is a general appreciation for art, unusual ideas, and imaginative, creative, unconventional, and wide interests (associated adjectives: artistic, curious, imaginative, insightful, original, and wide interest);
A *Agreeableness* is a dimension of interpersonal relations, characterized by altruism, trust, modesty, kindness, compassion and cooperativeness (associated adjectives: appreciative, forgiving, generous, kind, sympathetic, and trusting);
C *Conscientiousness* is a tendency to be organized and dependable, strong-willed, persistent, reliable, and efficient (associated adjectives: efficient, organised, reliable, responsible, and thorough).

There are several versions of the FFM questionnaire: NEO PI-R with 240 questions ('items'), 30 facets, and five domains; the older NEO-FFI with 180 items, etc. A shorter version of the Revised NEO Personality Inventory (NEO-PI-R), the NEO-Five Factor Inventory (NEO-FFI), has 60 items (12 per domain and no facet structure) selected from the original items (Costa & MacCrae, 1992). This shorter questionnaire was revised (McCrae & Costa, 2004) after Egan et al. demonstrated that the robustness of the original version should be improved (Egan et al., 2000). NEO-FFI was designed as a brief instrument that provides estimates of the factors for use in exploratory research.

The combination N↑, A↓, and C↓ for substance abusers was reported by McCormick et al. (1998). According to McCormick et al. (1998), the cocaine users were characterized by higher levels of E and O, whereas polysubstance users were characterized by lower levels of A and C .

We expected that drug usage would be associated with high N, and low A and C. This combination was observed for various types of psychopathy and deviant behavior, for example, in analysis of the *'dark triad' of personality*, Machiavellianism, Narcissism and Psychopathy (Jakobwitz & Egan, 2006).

Two additional characteristics of personality are proven to be important for analysis of substance use, Impulsivity (Imp) and Sensation Seeking (SS):
Imp *Impulsivity* is defined as a tendency to act without adequate forethought;
SS *Sensation Seeking* is defined by the search for experiences and feelings, that are varied, novel, complex and intense, and by the readiness to take risks for the sake of such experiences.

Relations between personality traits and drug consumption

There are numerous *risk factors* for addiction, which are defined as any attribute, characteristic, or event in the life of an individual that increase the probability of drug consumption. A number of such attributes are correlated with initial drug use, including genetic inheritance as well as psychological, social, individual, environmental, and economic factors (Cleveland et al., 2008).

The important risk factors are likewise associated with a number of personality traits (Dubey et al., 2010, Bogg & Roberts, 2004). A number of studies have illustrated that personality traits are associated with drug consumption. Meta-analysis of associations between the personality traits and specific depressive, anxiety, and substance use disorders in adults showed that all diagnostic groups were high on N and low on C (Kotov et al., 2010). This analysis involved 175 studies published from 1980 to 2007.

Several study of opioid dependent samples demonstrate high N, low C, and average O (Brooner et al., 1994, Carter et al., 2001, Kornør & Nordvik, 2007). There are also some controversions: Norvegian group of opioid users demonstrated lower E (Kornør & Nordvik, 2007), whereas US groups do not deviate in E from the norm significantly (Brooner, 1994, Carter et al., 2001). O, A, were observed lower in Norvegian group of drug dependent patients than in control but for this sample size (65 patients) the difference is not significant.

It was shown that high SS is associated with increased risk of substance use (Zuckerman et al., 1972, Liraud & Verdoux, 2000, Kopstein et al., 2001). Imp has been operationalised

in many different ways (Evanden, 1999). It was demonstrated that substance use disorders are strongly associated with high personality trait Imp scores on various measures (Verdejo-Garcia et al., 2008, Loree et al., 2015). Moreover, Imp score has significant impact on the treatment of substance use disorders: higher Imp implies lower success rate (Loree et al., 2015). It is possible that psychosocial and pharamacological treatments that may decrease Imp will improve substance use treatment outcomes (Loree et al., 2015).

Impulsivity has been shown to predict aggression and heavy drinking (McMurran et al., 2002). Poor social problem solving has been identified as a potential mediating variable between impulsivity and aggression. It is likely that the cognitive and behavioural features of impulsivity militate against the acquisition of good social problem-solving skills early in life and that these deficits persist into adulthood, increasing the likelihood of interpersonal problems.

A model was proposed, which attributes substance use/misuse to four distinct personality factors: SS, Imp, anxiety sensitivity (AS), and introversion/hopelessness (I/H). These four factors form a so-called Substance Use Risk Profile Scale (Conrod et al., 2000). The model was tested on groups of cannabis users (Conrod et al., 2000, Woicik et al., 2009, Hecimovic et al., 2014). It was demonstrated that SS was positively associated with expansion motives, Imp was associated with drug availability motives, AS was associated with conformity motives and I/H was associated with coping motives for cannabis use (Hecimovic et al., 2014). Therefore, the authors of this model concluded that four personality risk factors in the model are associated with distinct cannabis use motives.

The personality trait Imp and laboratory tests of neurobehavioral impulsivity measured different aspects of general impulsivity phenomenon. Relations between these two aspects are different in groups of heroin users and amphetamines users (even the sign of correlations is different) (Vassileva et al., 2014). Very recently, demographic, personality (Imp, trait psychopathy, aggression, SS), psychiatric (attention deficit hyperactivity disorder, conduct disorder, antisocial personality disorder, psychopathy, anxiety, depression), and neurocognitive impulsivity measures (Delay Discounting, Go/No-Go, Stop Signal, Immediate Memory, Balloon Analogue Risk, Cambridge Gambling, and Iowa Gambling tasks) are used as predictors in a machine-learning algorithm to separate 39 amphetamine mono-dependent, 44 heroin mono-dependent, 58 polysubstance dependent, and 81 non-substance dependent individuals (Ahn & Vassileva, 2016).

Two integrative personality dimensions capture important risk factors for substance use diorder (Krueger et al., 2002):

- *Internalizing* relates to generalized psychological distress, refers to insufficient amounts of behavior and is sensitive to a wide range of problems in living (associated

with overcontrol of emotion, social withdrawal, phobias, symptoms of depression, anxiety, somatic disorder, traumatic distress, suicide).

• *Externalizing* refers to acting-out problems that involve excess behavior and is often more directly associated with behaviors that cause distress for others, and to self as a consequence (associated with undercontrol of emotion, oppositional defiance, negativism, aggression, symptoms of attention deficit, hyperactivity, conduct, and other impulse control disorders).

Empirical results suggested co-occurrence of internalizing and externalizing problems among substance users (Chan et al., 2008). Nevertheless, the externalizing dimension differentiated heroin users from alcohol, marijuana, and cocaine users (Hopwood et al., 2008). Internalizing and externalizing symptoms can be evaluated in FFM (Derefinko & Lynam, 2007).

Analysis of the '*dark triad*' of personality showed that N was positively associated with psychopathy and Machiavellianism. The dark dimension of personality can be described in terms of low A, whereas much of the antisocial behaviour in 'normal' people appears underpinned by high N, low A, and low C (Jakobwitz & Egan, 2006).

The so-called '*negative urgency*' is the tendency to act rashly when distressed, and is also characterized by high N, low A, and low C (Settles et al., 2012).

Negative urgency predicted alcohol dependence symptoms in personality disordered women, drinking problems and smoker status in pre-adolescents, and aggression, risky sex, illegal drug use, drinking problems, and disordered behavior in college students.

Thus, the hypothesis about the personality profile N↑, A↓ and C↓ for drug users has a reliable background. We validated this hypothesis with our data and found, indeed, that for some groups of drug users it holds true. For example, for heroin and methadone users, we found this typical combination. At the same time, we found various deviations from this profile for other drugs. For example, for groups of recent LSD users (used less than a year ago, or used less than a month ago, or used less than a week ago), N does not deviate significantly from the mean but O and C do: O↑, C↓. Our findings suggest also that O is higher for many groups of drug users.

Roncero et al. (2014) highlighted the importance of the relationship between high N and the presence of psychotic symptoms following cocaine-induced drug consumption. Vollrath & Torgersen (2002) observed that the personality traits of N, E, and C are highly correlated with hazardous health behaviours. A low score of C, and high score of E, or a high score of N correlate strongly with multiple risky health behaviours. Formally, this profile associated with risk can be described as (C↓ AND E↑) OR N↑.

Flory et al. (2002) found alcohol use to be associated with lower A and C, and higher E. They also found that lower A and C, and higher O are associated with marijuana use. Sutin

et al (2013) demonstrated that the relationship between low C and drug consumption is moderated by poverty; low C is a stronger risk factor for illicit drug usage among those with relatively higher socioeconomic status. They found that high N, and low A and C are associated with higher risk of drug use (including cocaine, crack, morphine, codeine, and heroin). It should be mentioned that high N is positively associated with many other addictions like internet addiction, exercise addiction, compulsive buying, and study addiction (Andreassen et al., 2013).

An individual's personality profile contributes to becoming a drug user. Terracciano et al. (2008) demonstrated that compared to 'never smokers', current cigarette smokers were lower on C and higher on N. They found that the profiles for cocaine and heroin users scored very high on N, and very low on C whilst marijuana users scored high on O but low on A, and C. Turiano et al. (2012) found a positive correlation between N and O, and drug use, while increasing scores for C and A decreases risk of drug use. Previous studies demonstrated that participants who use drugs, including alcohol and nicotine, have a strong positive correlation between A and C, and a strong negative correlation for each of these factors with N (Stewart & Devine, 2000, Haider et al., 2002). Three high-order personality traits are proposed as endophenotypes for substance use disorders: Positive Emotionality, Negative Emotionality, and Constraint (Belcher et al., 2016).

The problem of risk evaluation for individuals is much more complex. This was explored very recently by Yasnitskiy et al. (2015), Valero et al. (2014) and Bulut & Bucak (2014). Both individual and environmental factors predict substance use, and different patterns of interaction among these factors may have different implications. Age is a very important attribute for diagnosis and prognosis of substance use disorders. In particular, early adolescent onset of substance use is a robust predictor of future substance use disorders.

Valero et al. (2014) evaluated the individual risk of drug consumption for alcohol, cocaine, opiates, cannabis, ecstasy, and amphetamines. Input data were collected using a Spanish version of the Zuckerman-Kuhlman Personality Questionnaire (ZKPQ). Two samples were used in this study. The first one consisted of 336 drug dependent psychiatric patients of one hospital. The second sample included 486 control individuals. The authors used a decision tree as a tool to identify the most informative attributes. The sensitivity (proportion of correctly identified positives) of 40% and specificity (proportion of correctly identified negatives) of 94% were achieved for the training set. The main purpose of this research was to test if predicting drug consumption was possible and to identify the most informative attributes using data mining methods. Decision tree methods were applied to explore the differential role of personality profiles in drug consumer and control individuals. The two personality factors, Neuroticism and anxiety and the ZKPQ's Impulsivity, were found to be most relevant for drug consumption prediction. The low sensitivity (40%) score means that such a decision tree cannot be applied to real life situations.

Without focussing on specific addictions, Bulut & Bucak (2014) estimated the proportion of teenagers who exhibit a high risk of addiction. The attributes were collected by an original questionnaire, which included 25 questions. The form was filled in by 671 students. The first 20 questions asked about the teenagers' financial situation, temperament type, family and social relations, and cultural preferences. The last five questions were completed by their teachers and concerned the grade point average of the student for the previous semester according to a five-point grading system, whether the student had been given any disciplinary punishment so far, if the student had alcohol problems, if the student smoked cigarettes or used tobacco products, and whether the student misused substances.

In Bulut & Bucak's study there were five risk classes as outputs. The authors diagnosed teenagers' risk of being a drug abuser using seven types of classification algorithms: *k*-nearest neighbor, ID3 and C4.5 decision tree based algorithms, naïve Bayes classifier, naïve Bayes/decision trees hybrid approach, one-attribute-rule, and projective adaptive resonance theory. The classification accuracy of the best classifier was reported as 98%.

Yasnitskiy et al. (2015) attempted to evaluate the individual's risk of illicit drug consumption and to recommend the most efficient changes in the individual's social environment to reduce this risk. The input and output features were collected by an original questionnaire. The attributes consisted of: level of education, having friends who use drugs, temperament type, number of children in the family, financial situation, levels of alcohol and cigarette smoking consumption, family relations (cases of physical, emotional and psychological abuse, level of trust and happiness in the family). There were 72 participants. A neural network model was used to evaluate the importance of attributes to diagnose the tendency towards drug addiction. A series of virtual experiments was performed for several test patients (drug users) to evaluate how possible it is to control the propensity for drug addiction. The most effective change of social environment features was predicted for each person. The recommended changes depended on the personal profile, and significantly varied for different participants. This approach produced individual bespoke advice to affect decreasing drug dependence.

FFM profiles of drug users have some similarity for all drugs (for example, N↑ and C↓), but substance abuse populations differ in details and severity of these deviations form the normal profile. This important observation was done by Donovan et al. (1998).

Data set and data analysis

The database was collected by an anonymous online survey methodology by Elaine Fehrman, yielding 2051 respondents. In January 2011, the research proposal was approved by the University of Leicester Forensic Psychology Ethical Advisory Group,

and subsequently received strong support from the University of Leicester School of Psychology Research Ethics Committee (PREC).

The database is available online (Fehrman & Egan, 2016, FehrmanDataUCI). An online survey tool from Survey Gizmo (Surveygizmo, 2011, Bhaskaran & LeClaire, 2010) was employed to gather data which maximised anonymity; this was particularly relevant to canvassing respondents views, given the sensitive nature of drug use. All participants were required to declare themselves at least 18 years of age prior to giving informed consent.

The study recruited 2051 participants over a 12-month recruitment period. Of these persons, 166 did not respond correctly to a validity check built into the middle of the scale, so were presumed to be inattentive to the questions being asked. Nine of these were also found to have endorsed the use of a fictitious drug, which was included precisely to identify respondents who overclaim, as have other studies of this kind (Hoare & Moon, 2010). This led a useable sample of 1885 participants (male/female = 943/942). It was found to be biased when compared with the general population being based on the data published by Egan et al. (2000) and McCrae & Costa (2004). Such a bias is usual for clinical cohorts (Gurrera et al., 2000, Terracciano et al., 2008) and 'problematic' or 'pathological' groups.

The sample recruited was highly educated, with just under two-thirds (59.5%) educated to, at least, degree or professional certificate level: 14.4% (271) reported holding a professional certificate or diploma, 25.5% (481) an undergraduate degree, 15% (284) a master's degree, and 4.7% (89) a doctorate. Approximately 26.8% (506) of the sample had received some college or university tuition although they did not hold any certificates; lastly, 13.6% (257) had left school at the age of 18 or younger.

Twelve attributes are known for each respondent: personality measurements which include N, E, O, A, and C scores from NEO-FFI-R, Impulsivity (Imp) from the BIS-11, Sensation Seeking (SS) from the ImpSS, level of education (Edu.), age, gender, country of residence, and ethnicity. The data set contains information on the consumption of *18 central nervous system psychoactive drugs including alcohol, amphetamines, amyl nitrite, benzodiazepines, cannabis, chocolate, cocaine, caffeine, crack, ecstasy, heroin, ketamine, legal highs, LSD, methadone, magic mushrooms (MMushrooms), nicotine, and Volatile Substance Abuse (VSA)* i.e. glues, gases, and aerosols. One fictitious drug (Semeron) was introduced to identify overclaimers. For each drug, participants selected either: they never used this drug, used it over a decade ago, or in the last decade, year, month, week, or day.

Participants were asked about various substances, which were classified as either central nervous system depressants, stimulants, or hallucinogens. The depressant drugs comprised alcohol, amyl nitrite, benzodiazepines, tranquilizers, solvents and

inhalants, and opiates such as heroin and methadone/prescribed opiates. The stimulants consisted of amphetamines, nicotine, cocaine powder, crack cocaine, caffeine, and chocolate. Although chocolate contains caffeine, data for chocolate was measured separately, given that it may induce parallel psychopharmacological and behavioural effects in individuals congruent to other addictive substances (Bruinsma & Taren, 1999). The hallucinogens included cannabis, ecstasy, ketamine, LSD, and magic mushrooms. Legal highs such as mephedrone, salvia, and various legal smoking mixtures were also measured.

The objective of the study was to assess the potential effect of the FFM personality traits, Imp, SS, and demographic data on drug consumption for different drugs, groups of drugs and for different definitions of drug users. The study had two purposes: (i) to identify the association of personality profiles (i.e. FFM+Imp+SS) with drug consumption and (ii) to predict the risk of drug consumption for each individual according to their personality profile.

Participants were asked to indicate which ethnic category was broadly representative of their cultural background. An overwhelming majority (91.2%; 1720) reported being White, (1.8%; 33) stated they were Black, and (1.4%; 26) Asian. The remainder of the sample (5.6%; 106) described themselves as 'Other' or 'Mixed' categories. This small number of persons belonging to specific non-white ethnicities precluded any analyses involving racial categories.

In order to assess the personality traits of the sample, the Revised NEO Five-Factor Inventory (NEO-FFI-R) questionnaire was employed (Costa & MacCrae, 1992). The NEO-FFI-R is a highly reliable measure of basic personality domains; internal consistencies are 0.84 (N); 0.78 (E); 0.78 (O); 0.77 (A), and 0.75 (C) (Egan, 2011). The scale is a 60-item inventory comprised of five personality domains or factors. The NEO-FFI-R is a shortened version of the Revised NEO-Personality Inventory (NEO-PI-R) (Costa & MacCrae, 1992) The five factors are: N, E, O, A, and C with 12 items per domain.

In our study, participants were asked to read the 60 NEO-FFI-R statements and indicate on a five-point Likert-type scale how much a given item applied to them (i.e. 0 = 'Strongly Disagree', 1 = 'Disagree', 2 = 'Neutral', 3 = 'Agree', to 4 = 'Strongly Agree').

The second measure used was the Barratt Impulsiveness Scale (BIS-11) (Stanford et al., 2009). BIS-11 is a 30-item self-report questionnaire, which measures the behavioural construct of impulsiveness, and comprises three subscales: motor impulsiveness, attentional impulsiveness, and non-planning. The 'motor' aspect reflects acting without thinking, the 'attentional' component, poor concentration and thought intrusions, and the 'non-planning', a lack of consideration for consequences (Snowden & Gray, 2011). The scale's items are scored on a four-point Likert-type scale. This study modified the response range to make it compatible with previous related studies (García-Montes et al., 2009).

A score of five usually connotes the most impulsive response although some items are reverse-scored to prevent response bias. Items are aggregated, and the higher the BIS-11 scores are, the higher the impulsivity level (Fossati et al., 2001) is. BIS-11 is regarded a reliable psychometric instrument with good test-retest reliability (Spearman's rho is equal to 0.83) and internal consistency (Cronbach's alpha is equal to 0.83 (Stanford et al., 2009, Snowden & Gray, 2011)).

The third measurement tool employed was the Impulsiveness Sensation-Seeking (ImpSS). Although the ImpSS combines the traits of impulsivity and sensation-seeking, it is regarded as a measure of a general sensation-seeking trait (Zuckerman, 1994). The scale consists of 19 statements in true-false format, comprising eight items measuring impulsivity (Imp), and 11 items gauging Sensation-Seeking (SS). The ImpSS is considered a valid and reliable measure of high risk behavioural correlates such as substance misuse.

It was recognised at the outset of this study that drug use research regularly (and spuriously) dichotomises individuals as users or non-users, without due regard to their frequency or duration/desistance of drug use (Ragan & Beaver, 2010). In this study, finer distinctions concerning the measurement of drug use have been deployed, due to the potential for the existence of qualitative differences amongst individuals with varying usage levels. In relation to each drug, respondents were asked to indicate if they never used this drug, used it over a decade ago, or in the last decade, year, month, week, or day. This format captured the breadth of a drug-using career, and the specific recency of use.

For decade based separation, we merged two isolated categories ('Never used' and 'Used over a decade ago') into the class of non-users, and all other categories were merged to form the class of users. For year-based classification we additionally merged the category 'Used over a decade ago' into the group of non-users and placed four other categories ('Used in last year-month-week-day') into the group of users. We continued separating into users and non-users depending on the timescale in this nested ''Russian doll" style. We also considered 'month-based' and 'week-based' user/non-user separations. Different categories of drug users are depicted in Fig. 1.

Analysis of the classes of drug users shows that part of the classes are nested: participants which belong to the category 'Used in last day' also belong to the categories 'Used in last week', 'Used in last month', 'Used in last year' and 'Used in last decade'. There are two special categories: 'Never used' and 'Used over a decade ago' (see Fig. 1). The data do not contain a definition of the users and non-users groups. Formally only a participant in the class 'Never used' can be called a non-user, but a participant who used a drug more than decade ago also cannot be considered a drug user for most applications. There are several possible ways to discriminate participants into groups of users and non-users for binary classification:

1. Two isolated categories ('Never used' and 'Used over a decade ago') are placed into the class of non-users with a green background in Fig. 1, and all other categories into the

class ‘users’ as the simplest version of binary classification. This classification problem is called ‘*decade-based*’ user/non-user separation.
2. The categories ‘Used in last decade’, ‘Used over a decade ago’ and ‘Never used’ are merged to form a group of non-users and all other categories are placed into the group of users. This classification problem is called ‘*year-based*’.
3. The categories ‘Used in last year’, ‘Used in last decade’, ‘Used over a decade ago’ and ‘Never used’ are combined to form a group of non-users and all three other categories are placed into the group of users. This classification problem is called ‘*month-based*’.
4. The categories ‘Used in last week’ and ‘Used in last month’ are merged to form a group of users and all other categories are placed into the group of non-users. This classification problem is called ‘*week-based*’.

The proportion of drug users among all participants is different for different drugs and for different classification problems. The data set comprises 1,885 individuals without any missing data. It is necessary to mention that the sample is intentionally biased to a higher proportion of drug users. This means that for the general population the proportion of illegal drug users is expected to be significantly lower.

The first result is the production of the database, cleaned and published in open access (Fehrman & Egan, 2016, Fehrman et al., 2016), and described in this book. We are sure that our book does not exhaust all the important information which can be extracted from this database, and will be happy if the database is used further in a variety of research and educational projects.

The second result is the personality profiles calculated for users and non-users of 18 substances (and for four definitions of users based on the recency of use) (Fehrman et al., 2015). These profiles can be used in many research projects; for example, for more detailed analysis of relations between the use of different drugs.

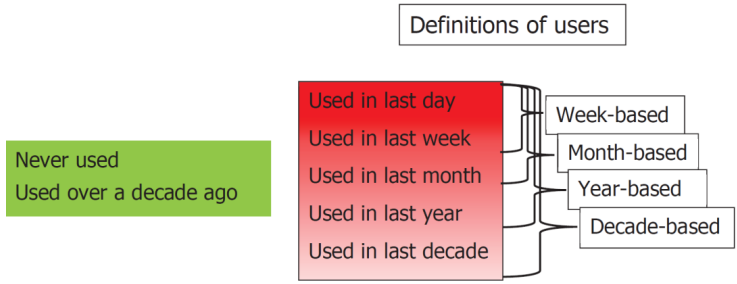

Fig. 1. Categories of drug users. Categories with green background always correspond to drug non-users. Four different definitions of drug users are presented

Our study reveals that the personality profiles are strongly associated with group membership to the users or non-users of the 18 drugs. For the analysis, we used the following subdivision of the sample T-score: the interval 44-49 indicated a moderately low score, (-) , the interval 49-51 indicated a neutral score (0), and the interval 51-56 indicated a moderately high (+) score.

We found that the N and O scores of drug users of all 18 drugs were moderately high (+) or neutral (0), except for crack usage for the week-based classification, for which the O score was moderately low (-). The A and C scores were moderately low (-) or neutral (0) for all groups of drug users and all user/non-user separations based on recency of use.

For most groups of illicit drug users the A and C scores were moderately low (-)with the exception of two groups: the A score was neutral (0) in the year-based classification ('used in last year') for LSD users and in the week-based classification ('used in last week') for LSD and magic mushrooms users.

The impact of the E score was drug specific. For example, for the week-based user/non-user separation the E scores were:

- moderately low (-) for amphetamines, amyl nitrite, benzodiazepines, heroin, ketamine, legal highs, methadone, and crack;
- moderately high (+) for cocaine, ecstasy, LSD, magic mushrooms, and VSA;
- neutral (0) for alcohol, caffeine, chocolate, cannabis, and nicotine.

Usage of some drugs were correlated significantly. The structure of these correlations is presented in Fig. 2. We found three groups of drugs with highly correlated use (Fig. 3). The central element was clearly identified for each group. These centres are: *heroin, ecstasy, and benzodiazepines*. This means that drug consumption has a 'modular structure', which is made clear in the correlation graph. The idea of merging correlated attributes into 'modules' referred to as *correlation pleiades* is popular in biology (Terentjev, 1931, Berg, 1960, Mitteroecker & Bookstein, 2007). The concept of correlation pleiades was introduced in biostatistics in 1931 (Terentjev, 1931). They were used for identification of a modular structure in evolutionary physiology (Terentjev, 1931, Mitteroecker & Bookstein, 2007, Berg, 1960, Armbruster et al., 1999). According to Berg (1960), correlation pleiades are clusters of correlated traits. In our approach, we distinguished the core and the peripheral elements of correlation pleiades and allowed different pleiades to have small intersections in their periphery (Fig. 3).

Additionally, a highly correlated 'smoking couple', cannabis and nicotine, is separated by an ellipse. E stands for ecstasy, H for heroin, B for benzodiazepines, and MM for magic mushrooms. Other drugs are denoted as follows: Am stands for amphetamines, Ca for cannabis, Co for cocaine, Cr for crack, Ke for ketamine, Lh for legal highs, LSD for LSD, Me for methadone, and Ni for nicotine. Edges represent correlations.

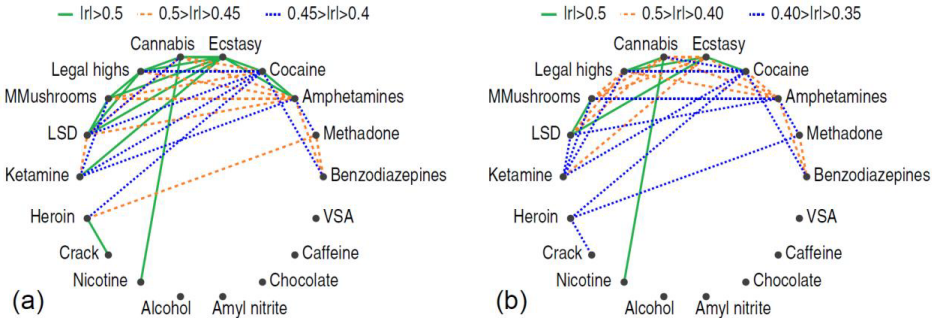

Fig. 2. Strong drug usage correlations: (a) for the decade-based classification problem, and (b) for the year-based classification problem

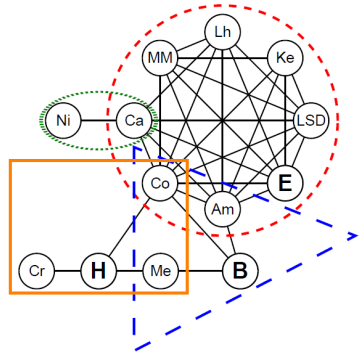

Fig. 3. Correlation pleiades for correlated drug use (in a circle, in a triangle and in a rectangle)

The three groups of correlated drugs centered around heroin, ecstasy, and benzodiazepines were defined for the decade-, year-, month-, and week-based classifications:

- The heroin pleiad includes crack, cocaine, methadone, and heroin;
- The ecstasy pleiad consists of amphetamines, cannabis, cocaine, ketamine, LSD, magic mushrooms, legal highs, and ecstasy;
- The benzodiazepines pleiad contains methadone, amphetamines, cocaine, and benzodiazepines.

In this study, we evaluated the individual drug consumption risk separately, for each drug and pleiad of drugs. We also analysed interrelations between the individual drug

consumption risks for different drugs. We applied several data mining approaches: decision tree, random forest, k-nearest neighbours, linear discriminant analysis, Gaussian mixture, probability density function estimation, logistic regression and naïve Bayes. The quality of classification was surprisingly high. We tested all of the classifiers by *Leave-One-Out Cross Validation*. The best results, with sensitivity and specificity greater than 75%, were achieved for cannabis, crack, ecstasy, legal highs, LSD, and VSA. Sensitivity and specificity greater than 70% were achieved for the following drugs: amphetamines, amyl nitrite, benzodiazepines, chocolate, caffeine, heroin, ketamine, methadone and nicotine. An exhaustive search was performed to select the most effective subset of input features and data mining methods for each drug. The results of this analysis provide an answer to an important question about the *predictability* of drug consumption risk on the basis of FFM+Imp+SS profile and demographic data. (Fehrman et al., 2015, Fehrman et al., 2018).

We also studied the problem of separation of users of different drugs. For this purpose, we selected three drugs: heroin, ecstasy, and benzodiazepines (the centres of the pleiades). The profiles of the users of these drugs are different (see Fig. 4) (the confidence level below is 95%):

- The mean values in the groups of benzodiazepines and ecstasy users are statistically significantly different for N (higher for benzodiazepines) and E (higher for ecstasy) for all definitions of users, for O (higher for ecstasy) for all definitions of users excluding the year-based, and for SS (higher for ecstasy) for all definitions excluding the month-based.
- The groups of benzodiazepines and heroin users are statistically significantly different for A (higher for benzodiazepines) for all definitions of users, for Imp (higher for heroin) and SS (higher for heroin) for all definitions of users excluding the week-based.
- Heroin and ecstasy are statistically significantly different for N (higher for heroin), E (higher for ecstasy) and A (higher for ecstasy) for all definitions of users and for Imp (higher for heroin) for all definitions excluding the week-based.

Conclusion

We have asked whether or not a psychological predisposition to drug consumption exists. Now, we can formulate the answer in brief:

- There is a significant difference in the psychological profiles of drug users and non-users.
- The psychological predisposition to using different drugs may be different.
- Machine learning algorithms can solve the user/non-user classification problem for many drugs with impressive sensitivity and specificity. Therefore, the question of predictability of the risk of drug consumption on the basis of personality traits and simple demographic attributes is answered in the affirmative.

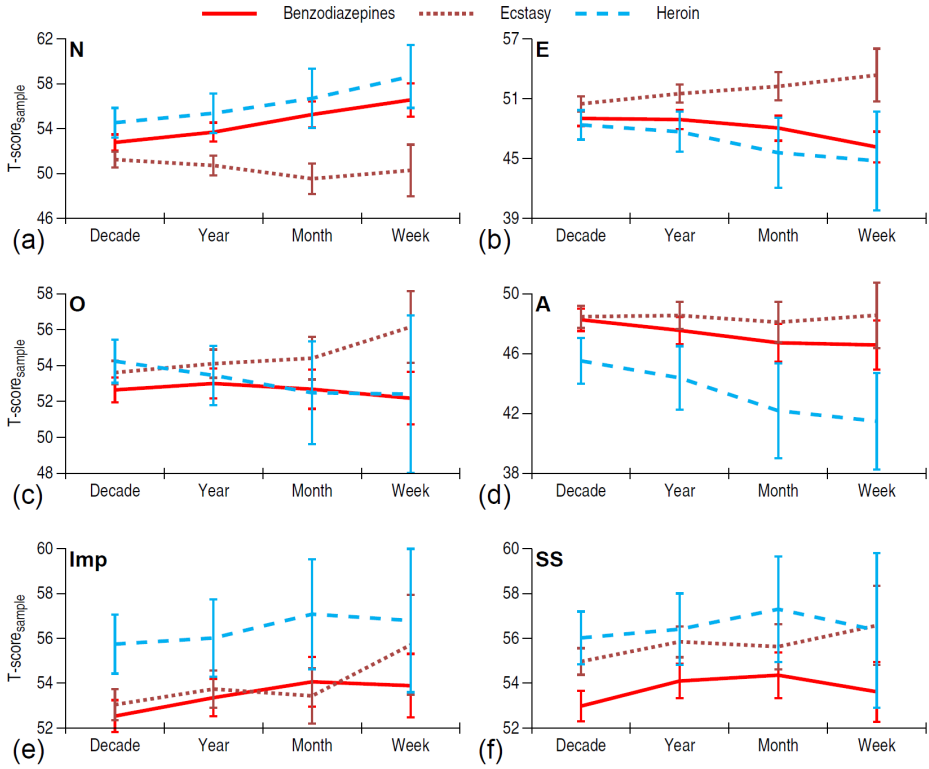

Fig. 4. Mean values with their 95% confidence intervals for significantly different psychological traits of benzodiazepines, ecstasy and heroin users: (a) N, (b) E, (c) O, (d) A, (e) Imp, and (f) SS

- Simple robust Fisher's linear discriminants are successfully employed for this classification.
- We describe the groups of drugs which have correlated use (correlation pleiades) and we can collect users of these groups of drugs together for the purpose of analysis.
- Mean profiles of users of different drugs are different. (This is explicitly proved for benzodiazepines, ecstasy, and heroin; this is obvious from the attached tables for many more pairs of substances.)

We confirm the findings of previous researchers that higher scores for N and O, and lower scores for C and A, lead to increased risk of drug use (Belcher et al., 2016). The O score is marked by curiosity and open-mindedness (and correlated with intelligence), and it is therefore understandable why higher O may be sometimes be associated with drug use (Wilmoth, 2012). Flory et al. (2002) found marijuana use to be associated with lower

A and C, and higher O. These findings have been partially confirmed by our study. Our results improve the understanding of the pathways leading to drug consumption. In particular, these pathways should form paths in the correlation pleiades of drugs.

The hypothesis we make above about types of risky behaviour is partially supported by the data. Moreover, we suggest that the type E↑, C↓ (Impulsives, Hedonists) is more typical among ecstasy and LSD consumers, whereas the type N↑, A↓ is more expected among heroin users. Detailed comparison of ecstasy and heroin users demonstrates that they are significantly different. Heroin users have higher N, and lower E and A. We also suggest that a high O-score is typical for many drug users (besides users of heroin, crack, and amyl nitrite) and therefore the O score cannot be excluded from the typology of risky behaviour. Moreover, very low A↓ is typical for VSA users. This is especially interesting because low A is the main significant predictor of violence in FFM and is central to the dark behaviours (Pailing et al., 2014). These comments may help in the further development of the typology of risky behaviour.

We have demonstrated that there are three groups of drugs with strongly correlated consumption. That is, drug usage has a 'modular structure'.

These results are important as they examine the question of the relationship between drug use and personality comprehensively and engage in the challenge of untangling correlated personality traits (the FFM, impulsivity, and sensation-seeking (Whiteside & Lynam, 2001)), and clusters of substance misuse (the correlation pleiades). The work acknowledged the breadth of a common behaviour which may be transient and leave no impact, or may significantly harm an individual. The detailed report will be published soon (Fehrman et al., 2018).

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A Rough Quarter of the Millennium. Revolutions Through the Lens of Google Ngram Viewer

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Abstract

This study focuses on the interdisciplinary issue of language corpora mining for the purpose of cultural analytics. The authors utilize the comparative cross -cultural approach to highlight the dynamics of "revolution" concept throughout two and a half centuries. They study concept application through the word occurrence in five languages by the means of Google Books Ngram Viewer and trace the waves of concept "popularity". Most of the word application peaks can be corresponded to the political events called "revolutions" but there is also an exception.

Keywords:

revolution, Ngram, cultural analytics, digital history, digital linguistics.

Introduction

The study of cultures through the language represented in text corpora by the means of digital techniques is an emerging interdisciplinary research trend. Since the introduction of "culturomics" as "the application of high-throughput data collection and analysis to the study of human culture" (Michel, 2011) the data-driven scholarship has turned into the new quantitative approach to humanities. The qualitative text analysis aimed at studying different aspects of human culture can be considered a subfield of the larger "cultural analytics" introduced by Lev Manovich in 2007 (Manovich, 2009).

The data analysis based on the big text corpora and performed with digital tools gives an opportunity to visualize large-scale changes by presenting dynamics in frequency changes. Depending on the data available and applied algorithms the research results

provide the overview of changing trends based on the specific criteria within the given period of time.

Digital tools that allow performing quantitative text analysis vary in functionality and openness. Despite its limitations the Google Books Ngram Viewer is currently the most accessible and simple tool for an independent researcher as it "enables fast and easy access to this pool of information without advanced technical knowledge" (Chumtong, 2017).

The Google Books Ngram Viewer gives a digitized overview of the culture: eight million books can be used for mining, searching, comparing words and word combinations in several languages. The simple but powerful tool gives a researcher a perspective that is very different from what can be done with traditional reading.

Theoretical framework

Content analysis as "assessment of the frequency and co-appearance of words, phrases, and concepts throughout a text" (Evans, 2011) is the approach that was earlier implemented mostly in linguistics. Applying digital tools for humanities made it possible to use content analysis in the study of history and culture.

A representative text corpus provides "insights into some of the cultural models used by certain people over time" (Swindle, 2014) which gives a researcher the opportunity to discover new aspects of culture that were not considered before due to the limitation of the methods available previously.

Comparing concept application in large scale text corpora from different languages and combining the results can be used "to measure differences and trends, ... standardize the process of comparison to bring up undiscovered matches" (Fox, n.d.). Cross-cultural comparison of a concept application may show similarities and differences in the particular concept application over time.

To make the content analysis with digital tools meaningful, the explored words or phrases must "have a relatively narrow range of interpretations such that their use in the data closely represents the intended underlying concept and the frequency of alternate or misrepresentative uses is relatively low" (Grant, 2015). While performing content analysis on the text corpora that belong to different languages a researcher also has to make sure that the explored concept has very similar dictionary meaning in the studied cultures. Otherwise, the research may return the results that are not related to intended concept value.

That is exactly the case with the concept "revolution" that we consider in this exploratory research. This word has very similar meaning in many languages including the ones studied so that it is often described as "international". The interpretation of the word

in these languages is very close to "a sudden, radical, or complete change" usually in political or social sphere (Merriam-Webster Dictionary). There is a second meaning of this word in English is "a progressive motion of a body around an axis". But this meaning is less common in the text corpora and is implemented mostly in technical texts. Nevertheless we need to take into account that this alternative meaning creates some semantic "noise" that changes the results for the English text corpus.

The purpose of the research is to discover the dynamics of the word application for the revolution as a radical change in political or social life considering other meanings as "noise".

The concept of "Revolution" has a long history and the various definitions from the various traditions in humanities and schools of thought dealing with the concept of revolution (Bain, 2015). It is also can be approached from several philosophical positions.

But for the purpose of this study we focus on the "revolution" as a combination of letters, a unigram that we explore with the help of the Google Books Ngram Viewer in five European languages. The goal is to make a general overview of word application dynamics for the 258-year period of "revolutions" using the optics of cultural analytics and text mining.

Statement of the problem

The aim of the study is to compare the occurrence of the word "revolution" in Google Books Ngram text corpora in five European languages: English, French, German, Spanish and Russian. The time period is chosen due to the interest in the major historical events called "revolutions": starting with the mid-eighteenth century (1750) and up to the latest year available in the Google Books Ngram Viewer (2008). That makes 258 years.

Our hypothesis is that the major political events called "revolutions" could have significant traces in one or several cultures which results in higher frequency of the word usage in the books. We also argue that some political events called revolutions that occurred during the specified period had major impact outside their language environment.

There has already been taken an attempt to compare the use of word "revolution" in different languages applying the Google Books Ngram Viewer and to find some matching political events (Fox, n.d.). But our research provides more in depth study of the correlations between the events viewed as revolutionary from within the particular cultures and the word "revolution" application changes as well as of the cross-cultural comparison of the changes dynamics.

Methodology

Google Books Ngram viewer gives access to over than 8 million books published in eight languages between 1500 and 2008 in eight languages. Though this text corpus cannot provide the precise values of the word application within particular of period of time it is enough to explore the major trends presented as "peaks" on the graph with the retrieved results.

We use Google Books Ngram Viewer to search unigrams that represent the word "revolution" in five European languages: English, French, German, Spanish and Russian.

For the Ngram Viewer queries in the five researched languages we used similar settings:

- The period was set to "between 1750 and 2008".
- The smoothing was set to the value of 4 to make a more visible dynamics of the change through the longer time intervals (9 years).
- All the word forms (WF) and their capitalized variants (cWF) in every researched language were combined into a single search query (SQ) according to the simple addition formula:

$$SQ = WF\_1 + cWF\_1 + WF\_2 + cWF\_2 + ... + WF\_N + cWF\_N$$

This approach allows us to produce cumulative occurrence graphs for word search including different word forms in every explored language. These graphs roughly present the changes within the same period of time and therefore can be compared.

To prove or disprove our hypothesis we need to check each individual graph presenting the word "revolution" occurrence in every studied culture against the timeline of events that are actually called revolutions within this language environment.

To create the timeline the events attributed as "revolutions" in the five corresponding languages we utilized Wikipedia as the source of language and historical information. To produce the list of events called "revolutions" in each particular culture we used Wikipedia in each particular language where the presented information on corresponding historical events is the result of contributors' agreement and cross-verification.

Though we understand Wikipedia limitations in terms of academic value we rely on this media project in recognizing common cultural meaning within particular language environment. While the variety of historiographical approaches makes the use of the particular term to address the particular event a matter of discussion, Wikipedia provides the representation of the current public consensus on the topic. Therefore we can consider events called "revolutions" listed in Wikipedia to be the most precise representation of the people's view on the revolutionary events inside each explored language environment at the current time.

Building the list of revolutionary events based on Wikipedia we included all major political events recognized as revolutions in the correspondent language sections of the online encyclopedia. As the chosen five languages are spoken in more than one country the lists consist of the revolutionary events which happened on the territories where each explored language was commonly spoken at the time of the particular event. That approach ensures that the listed event can be considered as the one occured within the particular language environment.

Having obtained the word occurrence graphs in the Google Books Ngram Viewer for each language we used arrow signs to highlight the major peaks of the unigram "revolution" application reflecting the rapid increases of word frequency in the explored text corpora.

In order to visualize the results of checking the word occurrence graphs against the created revolutionary events timelines we used graphical editing software. Adding layers with the events timelines to the word occurrence graphs makes it possible to synchronize, compare and collocate the word "revolution" application peaks with the actual political events culturally recognized as revolutions.

At the final stage of our research we produced the combined graph presenting all the defined peaks of word "revolution" occurrence from five individual language environments checked against all the political events that are culturally recognized as revolutions for the specified time period. This combined graph allows to collocate major peaks that appear in more than one language environment with the political events that can correlate with these peaks. The correlation presents relative impact of the revolutionary events on the word "revolution" popularity in books for the specified period.

Limitations of the Google Books Ngram Viewer

The diachronic analysis of the text corpora is highly sensitive to the quality of the analyzed data and the limitations of the tools (Baisa, 2015). In the course of our study we faced some issues with the metadata regarding the publication time of some books as well as some text recognition problems which were were discussed in the article by Pechenick, Danforths & Doods (Pechenick, 2015). The authors argue that "the library-like nature of the Google Books corpus will mean the resultant normalized frequencies of words cannot be a direct measure of the "true" cultural popularity of those words" as they prove that most of the scanned books belong to the academic literature and very few represent popular fiction.

There are also some limitations caused by the quality of automatic text scanning and indexing when the error cause some missing and incorrect data. These pitfalls may have significant impact especially if the the particular text corpus is not very large. That is the case with, for example, earlier books in Russian when the small number of scanned items leads to the bigger impact of the quality errors on the search results.

Findings

The five graphs obtained using similar settings make five very different visualisations of word "revolution" occurrence and its correlations with the political events culturally recognized as revolutions in five explored languages.

1. English Corpus Search Query

The English text corpus is the largest, and it combines British English and American English texts. Our first search query included two word forms (singular and plural) with their capitalized variations. That made a combination of four unigrams: "revolution + Revolution + revolutions + Revolutions".

The historical events called "revolutions" in the English part of Wikipedia are the following:

1. the American Revolution (1775–1783),
2. England's Last Revolution (1817),
3. the Texas Revolution (1835–1836).

These three events were represented on the timeline with oval (the longer event) and circle markers.

According to the obtained results the unigram "revolution" in English is significantly less common than its analogues in French, German and Spanish. There are six distinctive waves which are relatively regularly distributed over the time period of two and a half centuries:

Fig. 1. Timeline of revolutions combined with the N-gram graph (English)

1. the clearly shaped wave with the peak around the mid-1790s, which probably represents the French Revolution,
2. the gradually evolving wave with the peak around 1850,
3. the small wave with the peak around the mid-1890s,
4. the small with the peak around the early 1920s,
5. the wave with the peak around the mid-1930s,
6. and the most distinctive wave has the peak in the early 1970s.

After the last and the largest wave the frequency of the unigram "revolution" usage decreases, and in the beginning of the twenty-first century it decreases and reaches the level of the 1870s.

2. French Corpus Search Query

The search query in French was also a combination of the singular and plural word forms and their capitalized versions: "révolution + Révolution + révolutions + Révolutions".

Revolutions according to the French version of Wikipedia are the following:
1. Révolution française (French Revolution, 1789–1799),
2. Révolution brabançonne (Brabant Revolution, 1789–1790),
3. Heureuse Révolution (Liège Revolution or Happy Revolution, 1789–1791),
4. Révolution haïtienne (Haitian Revolution, 1791–1804),
5. La révolution de Juillet (The July Revolution in France, 1830),
6. Révolution belge (Belgian Revolution, 1830),
7. La révolution française de 1848 (February Revolution, 1848).

Fig. 2. Timeline of revolutions combined with the N-gram graph (French)

In the unigram occurrence graph (Fig. 2) we see two series of waves. The first series consists of five waves. This series starts in the end of the eighteenth century and lasts to the end of the nineteenth century:
1. the most significant wave with the peak around in the mid-1790s, which highly probably represents the French Revolution;
2. the second wave with the peak around the mid-1810s;
3. the third wave with the peak in the 1830s;
4. the fourth distinctive wave with the clear peak in the late 1840s - early 1850s, which probably can be referred to the Spring of Nations;
5. and a small wave with the peak around the mid-1860s.

The second series occupies the second half of the twentieth century and consists of three waves:
6. the small wave with the peak in the 1940s;
7. the distinctive wave with the peak around 1970;
8. and one more distinctive wave has the peak in the late 1980s which probably represents the bicentennial anniversary of the French revolution.

By the end of the researched period the occurrence of the unigram gradually decreases.

3. German Corpus Search Query

The search query in German included only two word forms (singular and plural) due to the capitalization of nouns in the language: “Revolution + Revolutionen”.

There are only two historical events referred to as “revolutions” in the German part of Wikipedia:
1. Deutsche Revolution von 1848/49 (German revolutions of 1848–49),
2. Novemberrevolution (German Revolution of 1918–19).

The unigram occurrence graph (Figure 3) has six waves.
1. the first clearly shaped wave with the peak in the the mid-1790s, which probably represents the French Revolution;
2. the second less distinctive wave in the mid-1830s;
3. the third clearly shaped wave with the peak in the late 1840s - early 1850s, which can be referred to the Spring of Nations;
4. the fourth wave with a peak in the early 1920s probably represents the Russian Revolution;
5. the fifth hardly distinctive wave is in the 1930s;
6. the sixth and the most significant wave lasts from the 1940s to the end of the researched perion. Its peak is in the early 1970s.

After that point the occurrence of the unigram decreases and by the end of the period it reaches the values similar to the 1910s.

Fig. 3. Timeline of revolutions combined with the N-gram graph (German)

4. Spanish Corpus Search Query

The search query in Spanish was a combination of two word forms (singular and plural) and their capitalized variants: "revolución + Revolución + revoluciones + Revoluciones".

The list of revolutionary events that can be found in the Spanish Wikipedia is extensive:

1. Revolución de Chuquisaca (modern Bolivia area, 1809),
2. Revolución de Mayo (modern Argentina area, 1810),
3. Revolución de 1820 (Spanish Revolution of 1820),
4. Revolución independentista (The republican revolution in Mexico, 1822–1823),
5. Revolución de 1854 (Spanish Revolution of 1854),
6. La Gloriosa o Revolución de Septiembre (Glorious Revolution in Spain, 1868),
7. La Rebelión cantonal o Revolución cantonal (Cantonal rebellion in Spain, 1873–1874),
8. Revolución radical de 1893 (The Argentine Revolution, 1893),
9. La Revolución filipina (Philippine Revolution, 1896–1898),
10. Liberal revolution in Paraguay (1904),
11. Revolución de 1905 (Argentine Revolution of 1905),
12. Revolución mexicana (The Mexican Revolution, 1910–1920),
13. The July Revolution in Ecuador (1925),
14. Revolución de 1934 (Spanish Revolution of October 1934),
15. Revolución social española de 1936 (Spanish Revolution of 1936),
16. Revolución del 17 de febrero de 1936 (February Revolution in Paraguay, 1936),
17. Revolución de 1952 en Bolivia (Popular revolution in Bolivia, 1952),
18. Revolución cubana (Cuban Revolution, 1956–1959),
19. Revolución venezolana (Bolivarian Revolution, 1999).

Fig. 4. Timeline of revolutions combined with the N-gram graph (Spanish)

There are eight waves which can be viewed as a single stair-step waveform (Figure 4). This wave starts growing in the late eighteenth century and slowly increases throughout the nineteenth century but it reaches the major peak in the second half of the twentieth century. The eight peaks equally distributed on the timeline are:

1. the first hardly distinctive peak around 1780,
2. the second peak in the 1830s,
3. the third peak around 1850,
4. the fourth around 1870,
5. the fifth peak in the 1890s – early 1900s,
6. the sixth small peak around 1920,
7. the seventh significant peak in the mid-1930s,
8. and the major (eighth) peak in the early 1970s, after which the occurrence of the unigram in the corpus gradually decreases.

Due to the high number of both revolutionary events and peaks it is difficult to trace the cross cultural influence in this particular graph.

5. Russian Corpus Search Query

Due to the variety of the noun word forms in the Russian language we had to create a complex query combining 14 unigrams (2 variants of the 7 word forms): “революция + Революция + революции + Революции + революцией + Революцией + революцию + Революцию + революциями + Революциями + революций + Революций + революциях + Революциях”. Further we address this combination as “революция”.

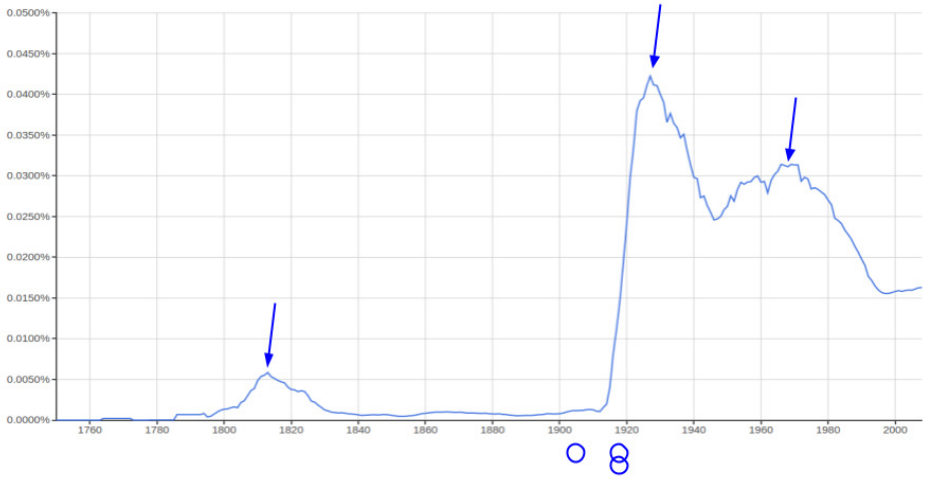

Fig. 5. Timeline of revolutions combined with the N-gram graph (Russian)

There are three historical events called revolutions in the Russian part of Wikipedia:
1. Революция 1905–1907 годов (Russian Revolution of 1905–1907),
2. Февральская Революция (February Revolution of 1917),
3. Октябрьская Революция (October Revolution of 1917).

There are three waves (Fig. 5) two of which cannot be referred to the historical events mentioned in the previous list:
1. a small wave with the peak around in the early 1830s, which is probably the late "echo" of the French Revolution;
2. a rapidly evolving wave ("a storm") with the peak in the mid-1920s, which can represent the Russian Revolution;
3. a less significant wave with the peak around 1970.

After the last wave the occurrence of the unigram decreases, but starting in the mid-1990s there is a small increase which is unique for the explored text corpora. The most distinctive feature of the graph is the rare occurrence of the unigram before the first decade of the twentieth century followed by the dramatic increase in the 1910s-1920s when the word "революция" becomes twice more common in Russian than in any other explored language.

Combined timelines

The results for all the five languages were combined in two timelines: the peaks of unigram occurrence in the language corpora (Fig. 6, arrows) and the historical events

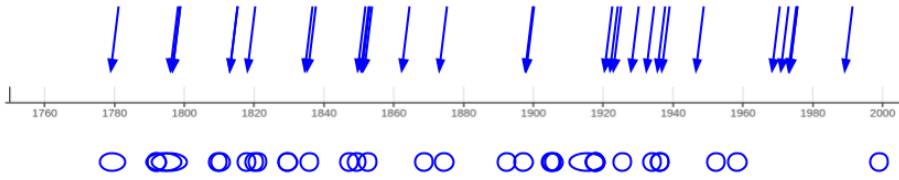

Fig. 6. Timeline events combined with the timeline of the peaks

called “revolutions” in Wikipedia (Fig. 6, circles and ovals depending on the duration of the even).

The first timeline with the unigram wave peaks shows five relatively long (lasting for approximately two decades and more) periods when there were no peaks in the occurrence of the “revolution” unigram:

1. before the late 1770s,
2. between the early 1870s and the late 1890s,
3. between the late 1890s and the early 1920s,
4. between the mid-1940s and the late 1960s,
5. after 1990.

The second timeline has only two similar periods when there were no events recognized as revolutions in the researched language cultures: before the 1780s and between the early 1960s and the late 1990s.

A discordance can be found during the second long period in the historical events timeline between the early 1960s and the late 1990s. While there are no events called “revolutions” in the researched cultures, the unigram occurrence peak timeline demonstrates the major wave in all the five languages. The graphs have distinctive peaks in the short historical period that starts in the late 1960s and finishes in the early 1970s. And for three of them (English, German and Spanish) this period is the time when the graphs reach their top values. The exceptions are the graph built for the French language corpus with higher peaks in the 1790s and in the 1840s, as well as the Russian language corpus with the highest peak in the 1920s.

A possible explanation for the 1960s-1970s wave is the popularity of the revolutionary rhetoric and wide recognition of conceptual frameworks focusing on “revolution” as the synonym of a rapid change (including concepts of “scientific revolution”, “technological revolution”, “sexual revolution”, “cultural revolution”, etc). The wave can also represent the influence of social and political events taking place outside the corresponding

cultures like the Chinese cultural revolution, or happening globally like the massive student movements. In our opinion this last large wave of "revolution" in the languages represents the shift of the focus from the actual political and social events in the national cultures to the global events. It can be viewed as a specific type of a slowly developing analogue of the "media-hype", the social amplification effect (Vasterman, 2005), but reflected in books of the particular time period.

Discussion

Every culture has its own idea of the great revolution in the history. The Great French Revolution, the American Revolution or the Russian Revolution produce significant traces in their cultures. The comparison of the word application frequency in the digitized texts corpora in different languages makes it possible to identify globally influential events that have their impact beyond the particular language environment. The results of cross-cultural comparison demonstrate the dynamics of the unigram in books that reflects increases and decreases in application of the corresponding concept.

Waves of popularity of the "revolution" concept appearing in different cultures throughout the last 258 years can often be related to the historical events. Nevertheless the events that are recognized as "revolutions" and represented in the books do not necessarily take place in political and social reality of these particular cultures. Researchers applying the cultural analytics methods should keep mind that there is possibility of such cross-cultural and global influence. In the course of the "rough" quarter of the millennium some cultures face the "phantom effect" of the revolutions which occurs when the amplified representation of the concept can be traced in the text corpus, while it has no real or single historical referent in the language environment.

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Modeling The Evolution Of Natural Language: Problem Statement

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Abstract

The author's purpose is to design a mathematical model of language evolution among the language using community and develop the software system modeling the evolution process. The software main task is to design individual historical scenarios of particular languages, language groups and families, and show the quantitative and qualitative changes in the grammatical and lexical structure of language over time, depending on the social organization of a group of language learners and users. In this paper the authors introduce the initial domain analysis and the basic level of the language evolution multi-level domain ontology that determines the base for the architecture of language evolution modeling software modules and the design of their interaction. The model is designed with the use of the applied logic language.

Keywords:

language evolution; evolutionary modeling; ontology; comparative linguistics; software development.

Introduction

One of the main tasks of comparative linguistics is to trace genetic relations between languages, as well as to determine the ways of their development and interaction with each other. The results of such studies influence our understanding of the historical scenarios of the civilization development.

The methods of establishing linguistic kinship use empirical estimates of the rate of language change based on comparison of lexical lists. However in some cases, such estimates are far from the required accuracy, which greatly complicates the work of specialists. This is due to the fact that glottochronology can rely only on processes with a more or less constant rate. And then the main difficulty arises. In various socio-cultural environments the same processes can take place in different ways. Thus, the conclusions, which are valid for one epoch or culture, can be erroneous for another. The subject of this study is the development of numerical methods for assessing quantitative and qualitative changes that occur in the grammatical, lexical and phonetic composition of a language over time, depending on the totality of such factors as the cognitive abilities of native speakers, as well as the social, economic and cultural structure of the group.

The study of linguistic evolution by the methods of direct experiment is inconceivable for ethical and many other reasons, therefore mathematical and computer modeling of language and linguistic activity plays a significant role in this field.

Theoretical framework

Natural language, as a feature of human cognitive activity and a species-specific feature, is the result of the evolution of Homo sapiens and the preceding species, as confirmed by studies of paleoanthropologists and primatologists.

One of the important features of Homo sapiens is the ability to perform complex collective interactions, and to build multi-path strategies involving a large number of participants. A prerequisite for this is the availability of a communication system serving to convey a wide variety of information. In addition, information can be repeatedly transferred from one participant to another. One of the reasons for the success of the community is that the communication system is well established, and the community-built strategies are successful. From this point of view, any knowledge received by the community must be formulated in such a way that it can be transmitted using a communicative system without bearing significant losses. A prolonged stabilizing selection in this direction led to the appearance of a phenomenon that we call human language. It is not only the way to conduct communication, but also a means to organize knowledge. That is why the study of processes occurring in the language are of such interest.

Like all other species-specific features, natural language is affected by natural selection. Modern research quite clearly shows the presence of variability and heredity in natural language. Comparativists often note the similarity of biological and linguistic evolution.

The pre-literate language, in contrast to the genetic material of the extinct species, is almost elusive. It is very difficult to reliably restore it beyond some (not very large) time depth. On the other hand, language changes, inheritance and selection occur much faster than similar processes in biological evolution. In modern conditions of

global communication such changes sometimes take place not in years but in months. Therefore, to identify the patterns of language development, it is not necessary to look into the distant past. Models of language evolution can be built on the basis of modern data and observations.

Evolutionary modeling is an independent field of experimental research. Most of the evolutionary research models are designed to study the different stages of biological evolution.

Due to the fact that language evolution, according to experts, is similar to biological evolution, it seems possible to apply methods of modeling biological evolution to natural language.

In a general sense, evolutionary theory describes the dynamics of the composition of a set of reproduced structures. Selection always exists when the next generation of reproducible structures (a collection of functional units) is not an exact copy of the previous one.

There are many computer models of so-called artificial life. The main idea of computer modeling of evolution is to create a population of agents that have the ability to reproduce, as well as a set of some other properties that determine their behavior. Among these properties there may be the following: the ability to accumulate and lose some resource (the ability to eat and consume energy), the ability to receive signals from the environment, including other agents, the ability to act on the basis of received signals, the ability to analyze signals from the environment and make decisions about subsequent actions based on this analysis, and others.

Evolutionary principles in a broad sense extend not only to biological objects, but also to complex chemical molecules and information structures. In fact, biological evolution is the evolution of self-replicating information structures of genes encoding their own chemical activity. The units of the communicative system (not the language yet, but its direct predecessor) do not code their own activity, but have an informational value that affects the quality of life and the life span of the individual (or a group of individuals) involved in using the communicative system. Language, undoubtedly, is the heir of the communicative systems of animals, more developed and advanced, but, nevertheless, the heir. The gap between animal communication systems and human language seems enormous, but in fact there are more commonalities between them than differences. Modern research shows that animal communicative systems possess such properties of the human language as semantics, productivity, transferability, and cultural continuity. And the higher monkeys are able to learn the human language, fully use it and train other monkeys. It is likely that the difference between the human language and the communicative systems of animals is not in quality, but in quantity, and there is no fundamental difference between these phenomena at all. Different species use different

methods of communication. At least three types of communication - verbal, visual (graphic, gestural, facial) and tactile (for people with visual and hearing impairment) – are available for Homo sapiens. The most developed for Homo sapiens are the verbal and graphic types of communication (oral speech and printed text), so the concept of natural language often boils down to these two types of communication, but is not limited to them.

Until now, there has been no consensus on whether the natural language of Homo sapiens is the product of directional selection, acting on a similar feature of the preceding species, or is the result of a random mutation that has so changed the brains of higher apes that they have acquired language ability comparable to ours. But in any case, the natural language, as a system with heredity and variability, generates an evolutionary process. In this paper, the authors do not raise the question of the origin of the language and do not consider whether it is the result of random mutation or directional selection. The authors are interested in studying the evolutionary process occurring within the language itself and leading to changes in its composition.

The task of modeling a natural language

The task, with which any language modeling begins, is the modeling of the structure of the language. In this direction, many fruitful attempts have been made, although some issues still remain unresolved.

To design the model of natural language, one has to determine the crucial properties of the language:

- semantics – the property of language to encode information about the surrounding world;
- openness (productivity) – the property of language, through which an unlimited number of different utterances can be constructed from a limited number of structural units;
- cultural continuity – the general language ability is inherited at the genetic level, but there is no specific genetic predisposition to mastering one or another language, that is, different languages are inherited only through the mechanism of cultural inheritance;
- relocatability – the language makes it possible to encode information not only about events occurring in the location where the speakers are at the moment, but also information about events in the past, the future, events in another place and even information about events that cannot happen;
- discreteness – there are clear distinctions between the signs of the language;
- reflexivity – the property of language, through which the natural language can be described using the natural language;

- double division – the property of language, due to which, using meaningful structural units, it is possible to construct larger meaningful structural units, and the smallest significant structural units can be divided into even smaller ones that do not have meaning;
- hierarchy – the existence of a hierarchy in the use of different structural units of the language in the process of constructing utterances.

A natural language can be perceived as a system in the memory of a language user. The language consists of elements and has a structure. This makes it possible to use it for communication and information storage. Language is a communicative system, therefore an element of the language system should be a certain unit that has a semantic meaning. Such a unit can be a word.

In (Nolfi and Mirolli, 2010) language is represented by a semantic network, where each word of the lexicon of the language user is a node of the network. The connection between the two words means that these words are syntactically related. The set of such connections defines all the syntactic relations in the language of the language user. The structure of the syntactic network is described by an adjacency matrix, where 1 means the presence of a connection, and 0 – its absence.

In addition, speaking about the structure of the language, it is important to take into account that the language has not only a semantic, but also an identification component. Successful communication is possible only when the participants in the communication process can accurately identify the information they receive, mark out and recognize the semantic units and the connections between them. Verbal language has a phonetic form, i.e. a number of selection factors affecting the language will be associated with the features of reproduction and recognition of the sound series. In other words, each semantic unit of language should have its own phonetic form, sufficiently different from other phonetic forms of the language, so that the semantic unit can be unambiguously recognized. A significant role is played by the features of the device of the hearing aid and the auditory cortex of the human brain. In addition, the phonetic form of each semantic unit must be such as to ensure its reliable reproduction. A significant role is played by the structure of the articulatory apparatus and features of the structure and work of the motor cortex zone associated with articulation. In addition, the connection between the control centers of the reproducing and recognizing apparatus, without which the communication process is impossible, imposes some restrictions.

The need to reproduce and recognize a large number of semantic units leads to the appearance of double division, i.e. to the emergence of a set of phonemes, the combination of which encodes each individual semantic unit of language.

The selection affecting the natural language will affect not only its semantic component, ensuring the maximum adaptation of language users to the environment so that the

encoding of information about the environment by means of the semantic units of language leads to the creation of the most effective behavioral strategies. The selection will also affect the phonetic form of the language in such a way that the existing phonetic system will allow to reproduce (for transfer) the semantic units of the language in the most effective way, and also uniquely recognize them. In addition, it is necessary to take into account the mutual influence of these selection factors. That is, the variety of semantic units will affect the phonetic system: the more extensive is the set of semantic units, the more effective the phonetic system must be in order to provide unambiguous recognition and accurate reproduction. On the other hand, physiological limitations, which do not allow an infinite expansion of the phonetic system, will affect the diversity of semantic units.

Thus, in the process of studying the evolutionary processes occuring in the language, it is necessary to take into account both the semantic and the identification components of the natural language.

The task of modeling the inheritance process of the language

The next task is modeling the inheritance process of the language. There are many open questions. It is quite clear that language learning is based on data obtained from an external language environment. Children who have been moved to a language environment other than the language environment of their parents, acquire the language that surrounds them, and have exactly the same abilities for the language of their parents as other members of the language community. That is, there is no correlation between genotype and abilities for a particular language. Nevertheless, one of the most important features of higher animals is active learning. That is, the child, learning various skills, including language, chooses, so to speak, what to learn, that is, what to inherit. In fact, in this case it is difficult to talk about the independent choice of a learner. Nevertheless, the process of language acquisition is influenced by many factors (including those directly related to the learner), so that inheritance becomes selective. Many specialists see the difference between linguistic evolution and biological evolution in active learning. But in fact, active learning is replication with concomitant selection. Modern research in the field of epigenetic processes shows that in biological inheritance everything is also much more complicated than it seemed at first glance. As a rough approximation, in the process of ontogenesis inherited features compete for the opportunity to be fully realized. Taking this into account, it is possible to assume that the processes of biological and linguistic inheritance are not at all different. Of course, selection, affecting the language in the process of acquisition, is associated with the biological base of the language that is with the structure and work of the brain – not only particular, so-called language zones, but the whole brain in general, from innate

primary instincts to complex skills acquired through training. Any process of recognition of the stimulus and reaction to the stimulus requires a certain expenditure of energy. In this case, not only the energy costs associated with some action are important, but also the presence of positive reinforcement in response to the action. In addition, the human body has well-defined physical limitations on the recognition of stimuli and the rate of response to the stimulus, which also affects the process of the language acquisition.

Selection influences the language not only in the process of the language acquisition, but throughout the life of the individual, changing not the structure of the language (apparently), but its quantitative content and the priority of using certain elements of the structure, which in turn affects inheritance of language by the next generation. At this stage, the language is influenced by both external factors associated with social processes, and internal factors associated with the functioning of the brain. Because of the complexity of the organization of human society, it is sometimes difficult to draw a line and separate external social from internal mental and psychological processes. However one should not underestimate the influence of language on culture, and culture on language.

A very important issue, closely related to all the previous ones, is the organization of the language in the human brain. At the present stage of research there is no single and clear answer to this question. A significant role in understanding how the language was organized in the human brain was played by the so-called "grandmother's neurons". This idea was first voiced as a comic story in the lectures of Jerry Lettwin. Its essence lies in the fact that in the human brain there are neurons responsible for the person's memories of an object, event or phenomenon. And if it were possible to remove all these neurons, then all these memories would be erased from memory. This idea is certainly grotesque, but there is a rational grain in it. If there is information, then something must encode it. So there must be functional units of code that implement the data carrier features. If we talk about computers, then the functional units of machine code will be 0 and 1. If we talk about the genetic code, then the functional units are four nitrogenous bases – adenine, guanine, thymine and cytosine. For oral speech, you can distinguish phonemes, for written speech – letters or signs, etc. From this point of view, speech is considered not as an equivalent of language, but as a way of conveying information.

Traces of memory – groups of neurons and even individual neurons associated with certain concepts, were discovered as a result of instrumental studies of the brain, such as fMRI, PET and implantation of electrodes in the brain (in the process of detecting the foci of epileptic activity). That fully corresponds to the theory of structural nodes of MacKay (MacKay, 1987). Each such node as a group of neurons – it is entirely possible that the non-neighboring, but related to each other with synaptic connections – encodes a particular concept. In this case, it is likely that the same neurons can be involved in several different groups and can play different roles in them. At the present stage of

research, the work on brain mapping has not been completed, but many successful attempts are being made in this direction. As a result of the experiments, neural structures responsible for coding individual concepts and words, possessing meanings and pseudo-words (Kimppa et al., 2015), and structures responsible for solving problems associated with the syntactic hierarchy were singled out (Friederici et al., 2011). We will use the results of these studies as the basis of our model.

Statement of the problem

The goal of the work is to develop a software product modeling language evolution, which can give a significant refinement for assessing the rate of change of language by creating individual historical scenarios for the development of individual languages, language groups and families. The existence of mutable parameters will help the specialist to set the most suitable conditions for the scenario of language development.

For this, it is necessary to solve a number of theoretical and practical problems of development.

The tasks set in this work:

- The development of a mathematical model of the evolutionary process occurring in a natural language. This task includes a number of subtasks. Namely, the modeling of the structure of natural language in the brain of language user; modeling the language inheritance process, which in turn includes the task of modeling the communication process, which consists of the generation of messages, the transmission of messages, the receipt and processing of messages.
- Development of the project of the program system that is capable of modeling the evolution of the natural language. This task includes subtasks related to the development of the architecture of a software system based on a mathematical model; choice of system development tools and software platform.
- Development of a prototype software system, its testing, and discussion of the features of the prototype work with experts in the field of comparative linguistics.

Methods

To build a model of language evolution, we chose an ontological approach [Kleshchev and Artemieva, 2000], which makes it possible to make the model modular. This, in turn, will allow the model to be used to test various hypotheses of the evolution of a natural language and quickly adapt it to new knowledge and data that appear in this area literally every day.

The ontological approach allows us to describe arbitrarily diverse data and connections between them without sacrificing the accuracy of the descriptions. In addition, this

approach allows us to unambiguously describe the terms, the relationships between them and the constraints that exist in this field. In this study, we are dealing with at least three important components: the neurobiological component necessary to describe the structure of the language in the brain of the language user, and the acquiring process (inheritance), the linguistic component necessary to describe the structure of the language as a communication system, and sociological component, necessary for describing the process of interaction of language users, as a result of which communication links occurs. The terms defined by these fields of knowledge are rather heterogeneous and require a clear definition of the relationships between them within the framework of the task. The ontological approach allows to construct a hierarchical structure of terms and links in such a way that this will allow to use it in future as the basis of the architecture of the software system.

Model of ontology

We define the natural language of the species as a way of organizing and transmitting information within a group of individuals of this species.

The idea of the model is that the language can be represented in the form of a resource, consisting of a set of structural elements and distributed in the population of language users. As a result of communication, the resource is redistributed, while for some elements more copies are created than for others, so selection occurs.

To implement the basic model, we chose the following structural elements of the language:

- words – sign-semantic units that have their own meaning and their own form, so that when the form is violated the meaning is lost, and the constituent part of the concept enclosed in the word cannot be expressed using part of the given word;
- types of words – tags or labels of words, characterizing the possibilities and limitations of the use of words in the compilation of syntactic sequences;
- sequences of types of words – syntactic structures, sequences;
- phonetic identifiers – tags or labels of words that unambiguously characterize them for the recognizing and reproducing systems.

Population

The population has a set of characteristics on the basis of which the properties of individuals are generated and distributed.

For the term **population**, the following basic parameters can be distinguished:

- number – the number of individuals in the population at each step of the simulation;
- social structure is a scheme of communicative connections of individuals in the population, at each step of the simulation there can be only one social structure in

the population, but during the simulation there can be a change of social structures with a change in the communicative connections of individuals within the population;
- types of activity – a set of activities of individuals that determine some of their vocabulary;
- demographic dynamics – change in the population size during the simulation.

Individual

Native speakers (in the model – individuals) have a set of basic characteristics that affect their behavior in the model, i.e. the number and quality of communication links, the frequency of messages transmission, the process of processing messages. That, in turn, affects the condition of other individuals.

For the term **individual**, the following basic characteristics can be distinguished:

- age – a characteristic that reflects the duration of the existence of the individual (measured in simulation steps in the model);
- social status – a characteristic of the individual that determines the communicative connections of the individual with other individuals (may change during the work of the model);
- occupation – characteristic of the individual, which determines some part of his vocabulary;
- circle of communication – the set of individuals whom the given individual exchanges messages with;
- coefficient of connectivity with other individuals – a numerical characteristic that determines the frequency of the transmission of a message from one individual to another;
- threshold of understanding the words – percentage characteristic, which determines the intuition of communication;
- threshold of understanding the types of words – the percentage characteristic that determines the intuition of communication;
- threshold of understanding the sequences of types of words – a percentage characteristic that determines the intuition of communication;
- the (communicative) state of the individual – the state of the individual, reflecting its role in the communicative process.

Language of the individual

The individual's language at every step of the simulation is represented by a set of pairs of structural elements. Each pair consists of a structural element and its counter, reflecting the number of occurrences of this element in messages received by an individual before the current simulation step. In addition, the language of the individual includes the ability of the language acquisition.

Structural elements of the language:

- words;
- types of words;
- sequences of types of words;
- phonetic identifiers.

In the set of structural elements of an individual's language, two subsets can be distinguished, in general, not coinciding with the set of all structural elements of a given individual's language. This is a subset of the active language and a subset of the passive language. The inclusion into each of these subsets is determined by the value of the threshold of inclusion into the subset (common for all structural elements of the given kind of the given individual) and the value of the counter of occurrences of this structural element in the messages received by the individual before the current step of simulation.

For the term **language of an individual**, the following characteristics can be distinguished:

- the threshold for the entry of a structural element into the passive language;
- the threshold for the entry of a structural element into the active language.

Word.

The lexical composition of the language can be different for different model scenarios. To implement this diversity, we propose to divide the vocabulary of the language into the following main groups:

- basic vocabulary (analogue of the Swadesh word list);
- household vocabulary;
- professional vocabulary (related to labor, research, medical, military, political, commercial activities);
- social vocabulary (related to social status);
- cultural vocabulary (associated with cultural phenomena such as poetry, stories, etc.).

For the term **word**, the following characteristics can be distinguished:

- type of vocabulary – the word belongs to one or another kind of vocabulary (may vary during the simulation);
- the value of the occurrence counter – the number of occurrences of the word in the messages that the individual received before the current step of simulation.

Types of words

The grammatical composition of the language can be different for different model scenarios. But any grammar in this model always has the basic properties such as the presence of grammatical roles of words. Grammatical roles in the model are denoted by types of words, and types, in turn, are divided into the main groups of grammatical roles.

For the term **types of word**, the following characteristics can be distinguished:

- main group – object / action / relation (membership) / (adverbial) modifier of place / (adverbial) modifier of time;
- the value of the occurrence counter – the number of occurrences of the word type in messages that the individual received before the current step of simulation.

Sequence of types of words

Grammar rules in the model are defined by a set of sequences of types of words, from which statements of language are composed. The rules of grammar can be conditionally divided into basic and extended, which reflects their prevalence and the possibility of their use by individuals belonging to different social structures.

For the term **sequence of types of word**, the following characteristics can be distinguished:

- type of rule – basic / extended;
- the value of the occurrence counter – the number of occurrences of the type relationship in messages that the individual received before the current step of simulation.

Phonetic identifier

The sound of a word in a model is specified by a sequence of phonetic identifiers. In accordance with the characteristics of individual phonemes, phonetic identifiers in the model can be divided into corresponding types.

For the term **phonetic identifier**, the following characteristics can be distinguished:

- type of identifier;
- the value of the occurrence counter – the number of occurrences of the phonetic identifier in the messages that the individual received before the current step of simulation.

Message

A message – an ordered set of words, built on the basis of a subset of the active language of the individual in accordance to the grammatical rules of the individual's language and the rules for the occurrence of errors. The message is generated by the individual-sender, transmitted to the recipient, processed by the recipient, on the basis of which its language set is changed. Depending on the ability of the individual to intuitively perceive and from his passive language set, the message can be understood, not understood or partially understood by the individual. This characteristic determines the communicative success, which further influences the existence of a communicative connection with the individual who sent messages.

For the term **message**, the following characteristics can be distinguished:

- the status of a message on its way from one individual to another – the message is generated, transmitted, received and processed;
- the status of the message after processing by the recipient individual – the individual can understand, partially understand or do not understand the message.

The terms in the model of the population of language users exchanging messages can be represented by the diagram depicted in Fig. 1.

Discussion
Software system prototype

The mathematical model underlying the software system is developed on the basis of the ontological approach and is described in the language of applied logic. In this paper, a formal description of the model is not presented, it can be found in [Makusheva et al., 2017].

The project of the software system is developed; it includes a detailed description of its architecture and operating principle. Fig. 2 shows the architectural-context diagram of the software system.

The system consists of the following subsystems:

- Subsystem of data management. This subsystem is responsible for entering model parameters via the interface or from a file, and also for storing sets of modeling parameters in the form of profiles in a text file. After loading the data from the file, the subsystem checks it for errors and, in the absence of errors, processes it for further use by the program. Also, this subsystem is responsible for storing the results in a tabular or graphic file.
- The subsystem of modeling the evolutionary process. This subsystem generates data in accordance with the modeling profile, and then calculates the state of the model population of language users using the step-by-step method based on the parameters specified in the modeling profile.

The population of language users is a group of agents (individuals) possessing a language resource that they can transmit to each other. The population can reach several tens of thousands of individuals, thus it is not possible to manually enter the properties of each individual. To form a population of individuals with a common language, the user enters the values of the properties of the entire population and the language properties of the population, and the program system, based on this data, and then generates the parameter values for each individual. At each step of the simulation, individuals selected on the basis of the specified parameters exchange messages, as a result of which their individual language changes. In addition, individuals can “die” and “be born” and this

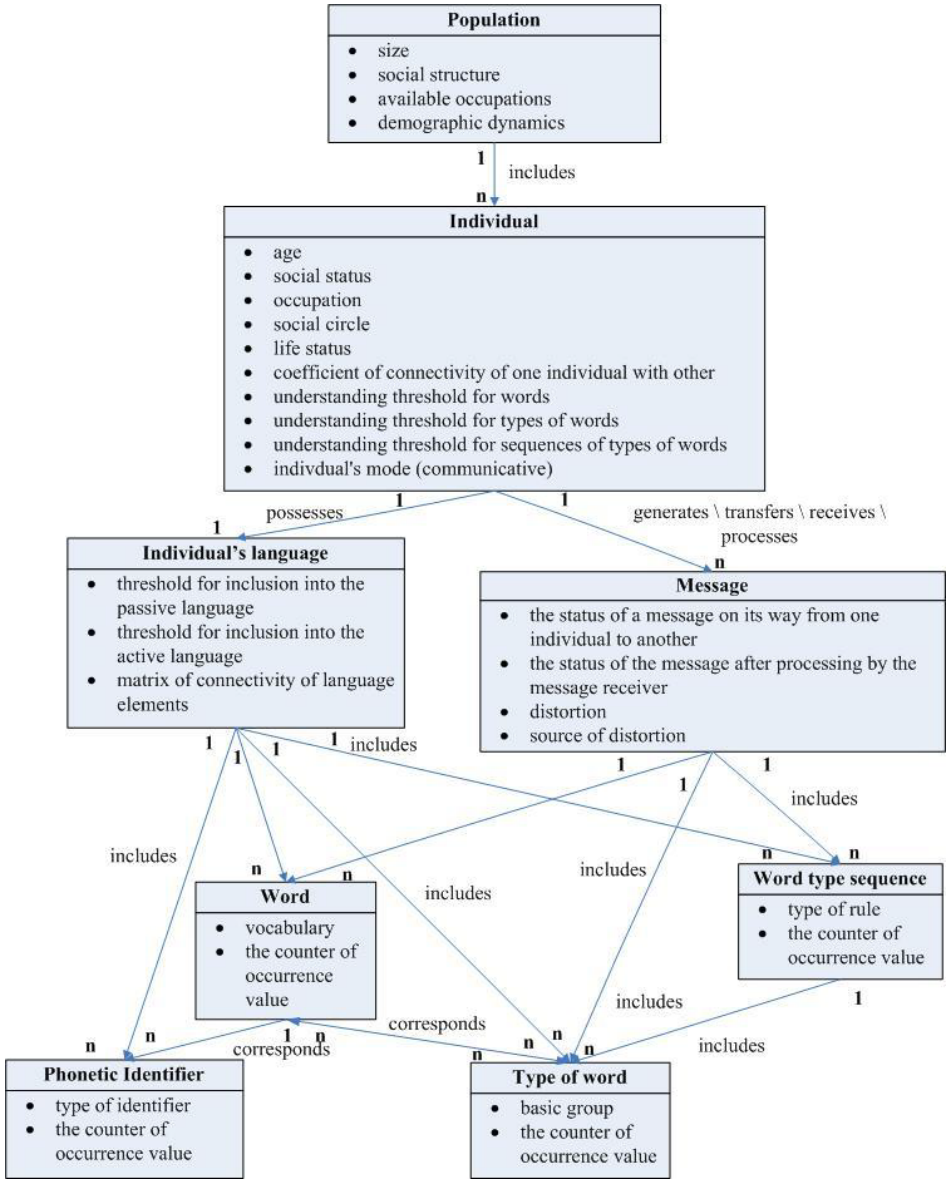

Fig. 1. Terms of ontology

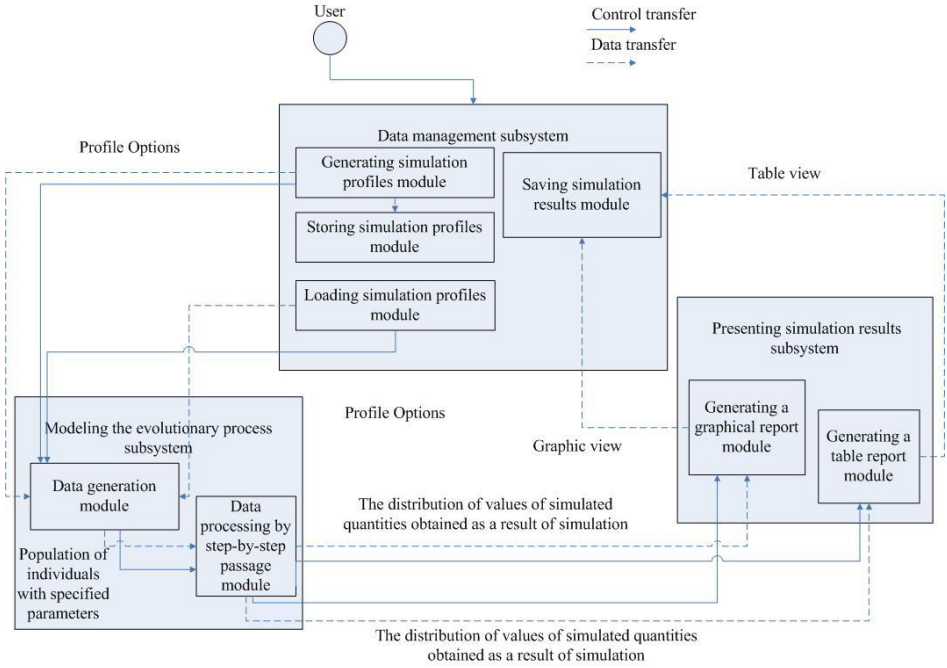

Fig. 2. Architectural Context Diagram of the Language Evolution Modeling System

changes the composition of the population. As a result, the composition and distribution of the language resource in the population is changing.

- A subsystem for presenting simulation results. The subsystem is designed to display the results in tabular or graphical form. The results can be displayed on the monitor or on the printer, and also saved to a file.

As a method for implementing a prototype, an integrated environment developed by Microsoft Visual Studio was chosen, with C ++ programming language being used. The prototype is implemented as a console application. This application generates model data, converts them according to the rules described in the mathematical model, and writes the result to a file. To verify the correct work of the prototype, tests were conducted with different initial data. In addition, an experiment was conducted, during which the distribution of language structures in the population of individuals that arose as a result of communication was modeled. In fact, this prototype is a "toy" that allows for evaluating the possibilities and limitations of the modeling system. This, in turn, allows experts to make the necessary adjustments, specify the research tasks and formulate requirements for the design of further experiments.

The developed prototype was discussed with experts in the field of linguistics. As a result, the problem of modeling phonetic changes that occurred in the English language in different historical periods was formulated. The aim of this simulation is to evaluate the contribution of various factors (neurobiological, physiological, linguistic, and social) that affect the selection process.

Conclusions

This work can be attributed to the direction in the evolutionary modeling of «Artificial Life». Such models allow to determine the factors influencing the evolutionary process, and to assess the degree of influence of these factors. In addition, such systems make it possible to conduct model experiments in those cases when a full-scale experiment is impossible. The authors hope that the developed system for modeling the evolution of natural language will make it possible to classify neurobiological, physiological, linguistic and social factors influencing the formation of a natural language, to determine their interrelations and mutual influence, which as a result will lead to a deeper understanding of the nature of the language and its role in the process of socio-cultural development of civilization.

To achieve these goals, it is naturally necessary to further develop the model, complicate the structure of the program system and discuss experiments with linguists.

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Community structures and character network dynamics in War and Peace

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Abstract

This paper applies network analysis to the study of character system and character dynamics in *War and Peace* by Leo Tolstoy. We employ graph theory to create a formal measureable model of character system and explore it both statically and dynamically. We then use this model to test two literary hypotheses concerning *War and Peace*. The first hypothesis is about the community structure of the novel. We test the assumption that network representation of character interactions in the novel can be easily clustered into communities of characters representing families, military units and other *meaningful* and *interpretable* groups. The second hypothesis is about the *war versus peace* antithesis that gave the novel its famous title. We try to measure the disruptive impact of war on social interactions within the novel using standard measures from graph theory, such as network density, diameter, average node degree and so on. The results seem to open up certain perspectives for quantitative analysis of literature with help of network analysis.

Introduction

Literary network analysis is a branch of digital literary studies that applies methods of network science to the study of literature. The rise of literary network analysis is commonly associated with the works of Franco Moretti, who provided the philological rationale for this sort of digital formalism in [Moretti 2011] using Shakespeare's *Hamlet* as a showcase. However, there is also substantial amount of earlier research dedicated to network analysis of literary work. In [Schweize & Schnegg 1998] anthropologists analyze the network of characters in *Simple stories*, a contemporary novel by Ingo Shulz depicting life in the former GDR after the unification of Germany [Alberich et al. 2002] explore the vast network of Marvel comics characters, extracted automatically from a total of 12942 comics issues. The authors apply theoretical apparatus from graph theory (see 'theoretical framework' below), namely network density, clustering coefficients, average node degree, average path length and other formal metrics of the resulting network. This study demonstrates that fictional networks are structurally similar to the social networks of the real world and can be investigated with help of standard approaches from social network analysis. In a follow-up study of the same Marvel universe [Gleiser

2007] all characters are additionally classified into heroes and villains, which enables authors to speculate on Marvel's marketing techniques [Gleiser 2007] demonstrate that most heroes are connected to each other within one huge connected component of the network, whereas villains do not form a unified group. This, the authors suggest, could result from Marvel's attempts to popularize new and yet unknown characters by pairing them with older well-known superheroes, such as Captain America or Superman. Other early network-related research includes several analyses of Shakespeare's plays [Stiller et al. 2003; Stiller & Hudson 2005], analysis of community structures in *Les Miserables* [Newman & Girvan 2004], comparison of rural and urban networks in XIX century British novels [Elson et al. 2010]. Finally, speaking of pre-Moretti studies on literary network analysis, we would like to note one little-known work by a Soviet literary scholar V. Sapogov [Sapogov 1974], which contains highly formalized analysis of character co-appearances in *The Forest* (*Les*) by Alexander Ostrovsky. This study can be viewed as a precursor to modern literary network analysis.

After [Moretti 2011] a lot more research on literary network analysis came around. Studies like [Trilcke et al. 2015; Trilcke et al. 2016; Fischer et al. 2017] employ network analysis to large-scale digital exploration of drama (in a way following Moretti's lead with *Hamlet*). Dramatic text with its inherent structure (acts, scenes, speeches) naturally becomes an easier target for automated network extraction and analysis. Some results include the fact that comic networks appear to be statistically denser than tragic ones, and the potential of network formalization to capture differences between specimens of different literary movements.

Unlike drama, prose usually lacks well-defined formal structure and therefore poses bigger challenges when it comes to network formalization and analysis. Nevertheless, there is a lot of new research on network analysis in prose. Some specimen include [Agarwal et al. 2012; Lee & Yeung 2012; Agarwal et al. 2013; Bodrova & Bocharov 2014; Ardunay & Sporleder 2014; Lee & Wong 2016; Grayson et al. 2016].

Theoretical framework

Graph theory

The theoretical framework for this study lies in the domain of graph theory. The practical field, which makes use of this theory, is also known as network analysis or network science. A network (or graph) is essentially a set of objects (nodes, vertices) and connections (edges, arcs) between them (see sample graph of literary characters in fig. 1).

This simple yet powerful formalism is used in a wide spectrum of research areas ranging from physics to political science. The reason for such universality is that so many things can naturally be formalized as a set of nodes and edges: from molecules and proteins

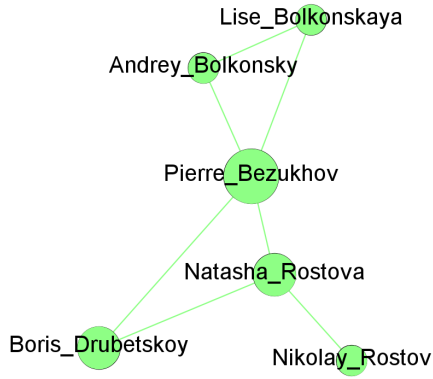

Fig. 1. Sample graph of literary characters

to geographical objects, transportations systems, societies, information channels and digital entities. Graph as a scientific abstraction is both a mathematical object suitable for formal analysis and a powerful means of data visualization and visual exploration. Smaller graphs are easy to layout and explore with the naked eye; however, there is a range of mathematical methods of network exploration which include various formal metrics for the relative importance of nodes (node degree, betweenness centrality etc.), methods of structural analysis of the whole network, and algorithms for community detection.

Important terms

Node degree – the number of connections each node has to other nodes. E.g. in fig. 1 Natasha Rostova has node degree 3, Pierre's degree is 4, and the average degree for all nodes in the network is 2,3.

Weighted graph – a graph that has weights on its edges. Depending on the exact formalisation, weights can represent strength, intensity, frequency or other properties of the connection between nodes. For instance, in a social communication network weights could be the frequency of communication between two individuals. An example of weighted graph is shown in fig. 2 (note the numbers on the edge lines that represent weights).

Weighted node degree – node degree (see above) with edge weights taken into account. E.g. in fig. 2 Natasha's weighted degree is 3 (2+1).

Shortest path length – the minimal number of edges between two nodes. Calculating this for all pairs of nodes in the graph and dividing by the number of pairs gives average

Fig. 2. A weighted graph for six *War and Peace* characters

path length of the entire network (it tends to be small in tight-knit strongly interconnected communities).

Density – the ratio of the number of edges in a graph to the maximum possible number of edges (which is if every node was connected to every other node).

Graph clustering – automatic community detection in a graph. Most community detection algorithms look for the easiest ways to split graph into separate subgraphs or attempt to find groups oa nodes that have many connections between each other and only few links to other nodes.

Network analysis of War and Peace: statement of the problem

We use network analysis as a research instrument to investigate character space and plot dynamics in *War and Peace* by Leo Tolstoy. The novel is undoubtedly one of the most influential fictional texts ever written in Russian, as well as one of the largest. The system of characters in *War and peace* is complex and evolving, which suggests it might be interesting to model it as a network and apply methods of network analysis. We use network theory to test a couple of literary hypotheses or just assumptions concerning the novel and its character space:

Assumption: the character space of the novel naturally clusters into groups: main families, different army units (and headquarters), political circles etc.

Grounds for the assumption: Tolstoy scholars often point out the importance of family unions in the novel (see e.g. [Bocharov 1971]), as well as the temporary family function

of the Pavlograd hussar regiment for Nikolai Rostov. It might be interesting to find out whether these unions can be registered formally in the same way communities are detected in the real-world networks.

Test: build a network of character interactions, apply network clustering algorithm

Assumption: the war-related parts of War and peace exhibit measurably different social dynamics than the peace-related ones;

Grounds for the assumption: the symbolic antithesis of War and Peace was what gave Tolstoy's novel its title; notable Tolstoy scholar G.S. Morson suggests that this antithesis is the 'central opposition' of the book, adding that "the salon and the battlefield represent the extremes of order and chaos – of 'peace' and 'war' – in War and peace" [Morson, 1987, p. 97]. We would like to know if this opposition is reflected in the intensity of social interactions within the novel. This is especially interesting since Tolstoy is said to have preferred describing individual war experience [Morson, 1987, p. 99], such as that of prince Andrey at Austerlitz or Nikolai at Schön Grabern and Ostrovna. Also, [Trilcke et al. 2015a] show that for centuries comedy and tragedy have been consistently different in the densities of their networks. This might be an indication that density and other network measures might capture certain aspects of social dynamics in fiction.

Test: extract character networks for compatible segments of the novel that describe either peacetimes or war; measure network metrics (see 'theoretical framework' above) and check if changes in these correlate with the segment being predominantly peaceful or predominantly about war.

Network extraction method

Formalizing nodes and edges

To convert any text into network, one must first formalize nodes and edges of that network. In most literary network analysis works the nodes represent all or some characters[1] of the work(s). In our case we limited ourselves to the set of characters available on Wikipedia [Wikipedia list of War and Peace characters]. Formalisation of edges is usually more complicated. They are typically expected to reflect some sort of relations or interactions between characters. There are two main approaches to operationalizing such formalisation.

1. The most simplistic approach suggests that characters somehow 'interact' if their mentions co-appear within a 'text window' of a certain length (e.g. one sentence or 15 words). To filter out purely accidental co-appearances we might only take into account the connections that repeat at least N times.

[1] [Lee & Yeung 2012] in their network analysis of the *Bible* use both characters and geographic entities as network nodes.

2. More complex set of approaches consists in trying to extract interactions or relations from text employing natural language processing techniques. This might involve syntactic parsing, rule based or statistical information extraction methods, extraction of direct speech and dialogues from text and so on.

Since connections between characters are registered repeatedly in different parts of the text, we can use the number of these repetitions to make our graph more informative. We encode the number of connections between each pair of characters as the *weight* of the edge (see 'theoretical framework' above for more information on weighted graphs). In our visualisations thickness of edges is proportional to edge weights. Edge weights are also accounted in the community detection algorithm we employ.

Evaluation of networks

One could also use a hybrid approach combining both strategies. To determine the best method for our case we created a hand-coded 'gold standard' of 20 chapters where character interactions were marked up manually. Our first approach was based on character co-occurrence within one sentence. The second approach depended on syntactic structures indicating an interaction between characters. For this second approach we recorded an interaction each time two characters together filled slots within one predicative frame (e.g. "*Berg* gave his arm to *Véra*" or "*Natásha's* wedding to *Bezúkhov*"). We then tested different network extraction techniques against our 'gold standard', using standard metrics of precision, recall, and F-measure. The results are shown in the Table 1 below.

Table 1. Performance of different network extraction approaches

	Co-occurrence within one sentence, no frequency filter	Co-occurrence within one sentence, requires at least 2 co-occurrences to create edge	Co-occurrence within one sentence, requires at least 3 co-occurrences to create edge	Co-occurrence within one sentence, requires at least 4 co-occurrences to create edge	Co-occurrence within one sentence, requires at least 5 co-occurrences to create edge	Syntax-based interaction extraction
Precision	40,5%	57,1%	71,8%	76,7%	77,3%	78%
Recall	68,9%	59,4%	37,8%	31,1%	23%	52,7%
F-measure	51%	58,3%	49,6%	44,2%	35,4%	62,9%

As one would expect, the crude co-occurrence approach performs the worst in terms of precision (40,5%), yielding a lot of false positive results (i.e. redundant connections).

Precision of co-occurrence approach can be increased by introducing a filter and only taking into account those co-occurrences which repeat at least N times. With N = 2 this gives a big improvement in precision that surpasses the ensuing drop in recall, resulting in a better overall F-measure. However, syntax-based approach turns out to be the most precise method (78%), and while it loses some points in recall to the less-strictly filtered versions of co-occurrence method, it still has a better overall F-measure (62,9%). The best total outcome, though, is produced from the combination of the two approaches and a co-occurrence filter with N = 3 (67,6% F-measure, see Table 2):

Table 2. Performance of combined network extraction approaches

	Syntax based + co-occurrence, no filter	Syntax based + co-occurrence, filter with N = 2	Syntax based + co-occurrence, filter with N = 3	Syntax based + co-occurrence, filter with N = 4	Syntax based + co-occurrence, filter with N = 5
Precision	41,4%	58%	72,3%	76%	77,1%
Recall	71,6%	69%	63,5%	60%	59,5%
F-measure	52,5%	63%	67,6%	0.67%	67,1%

Discussion

Static network analysis

Now that we have established the optimal method for network extraction, we can finally proceed to network analysis. In this section we combine visual analysis and the methods of graph theory described in the 'theoretical framework' above. The visualisations are made using force-based graph layout algorithm, and the size of nodes corresponds to weighted node degree. The entire network of characters is shown in fig. 3.

From the visual analysis of this network, one can immediately distinguish the big community of military commanders grouped around the Russian commander-in-chief Mikhail Kutuzov (fig. 4).

However, it is hard to visually detect any more distinct communities. To test our first assumption, let us apply clustering algorithm. We use modularity clustering [Blondel et al. 2008] to cluster our network into communities. The results are shown in the fig. 5 (communities are color-coded and numbered).

The resulting community structure corresponds to our knowledge of character groups and interactions in War and peace. Most groups are easily interpretable. Community #0 obviously contains the so-called 'Rostov world' – Natasha, Sonya, Vera, old count Ilya

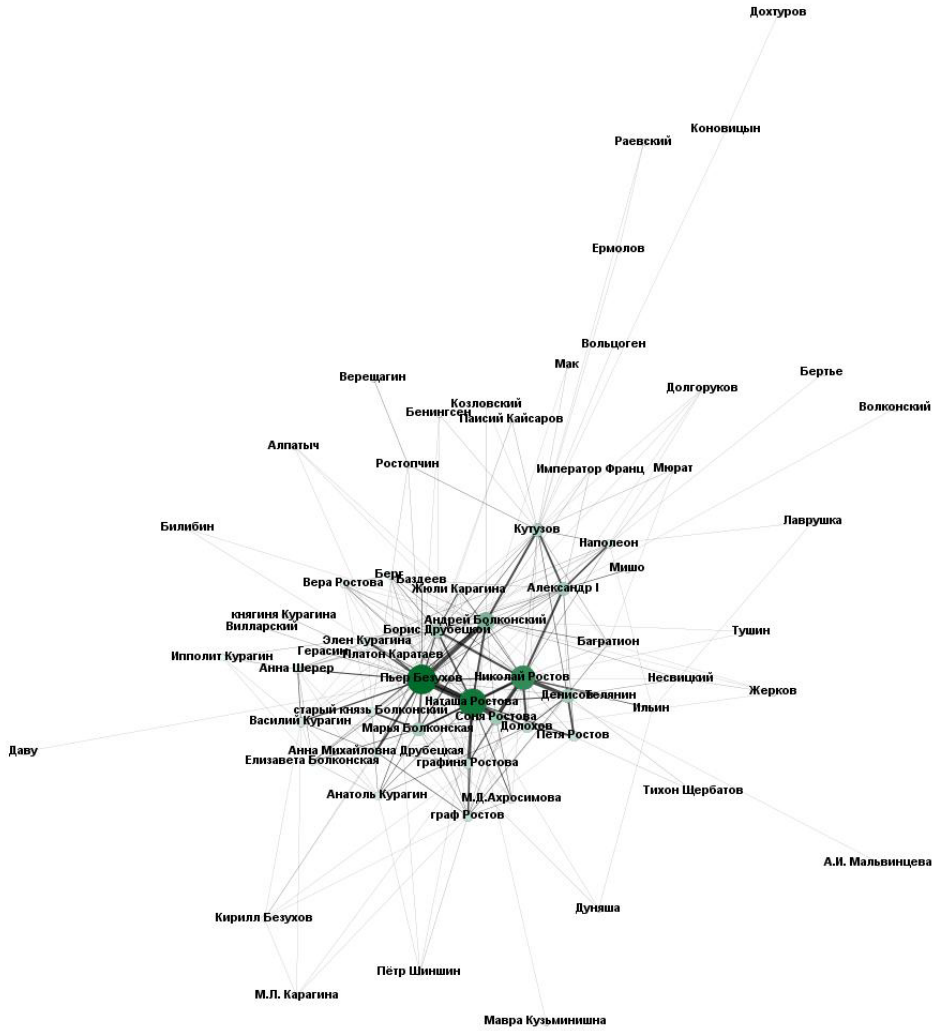

Fig. 3. Network of named characters in *War and Peace*

Rostov, countess Natalya Rostova and her cousin Piotr Shinshin, plus the representatives of old muscovite nobility grouped around the family. Community #1 is the army circle of Nikolai Rostov combined (through Denisov) with the guerrilla unit from the fourth volume of the book. Being able to detect this community is especially valuable since it is actually explicitly stated in the book that for Nikolai “the whole world was divided

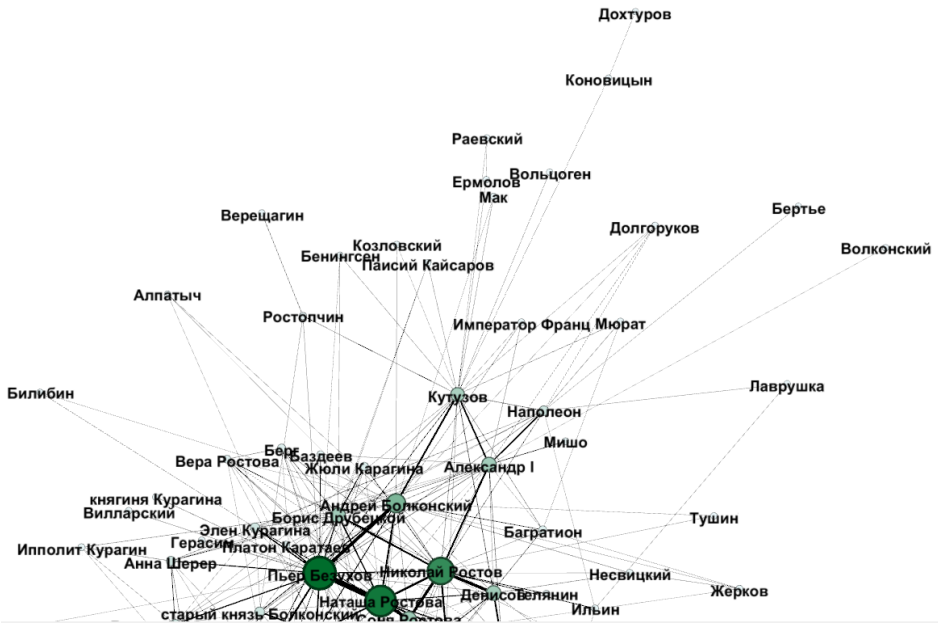

Fig. 4. Network of named characters in *War and Peace*, fragment

into two unequal parts: one, our Pávlograd regiment; the other, all the rest". Community #3, the biggest of all, consists almost entirely of the military commanders, Russian and Austrian/Prussian allied generals. This community also contains French marshal Murat, whose link to Kutuzov is somewhat tentative: there is no direct interaction, but the Russian commander mentions Murat several times, and at certain points they are simply mentioned together by Tolstoy in his descriptions of battles. Community #4 includes the two emperors, Alexander I and Napoleon, together with the messengers (Dolgorukov, Michaud) through whom they communicate, and some of their closest companions (Volkonsky, Berthier). Community #7 basically unites the inhabitants of the Bald Hills, Bolkonsky family estate. It also accidentally includes Anatole due to his visit to the Bald Hills with his father in an unsuccessful attempt to marry princess Marya.

At the same time, it is obvious that when we attempt to analyse the entire network of such a big novel, we run into problems. [Moretti 2011] points out that conversion of *Hamlet* into network turns time into space, which makes it possible to compress "four hours of action" into one picture. However, *War and peace* is much larger than *Hamlet*, it contains more subplots, scene changes and is generally bigger in every way imaginable. Such a radical compression leads to the overlap of information from different parts

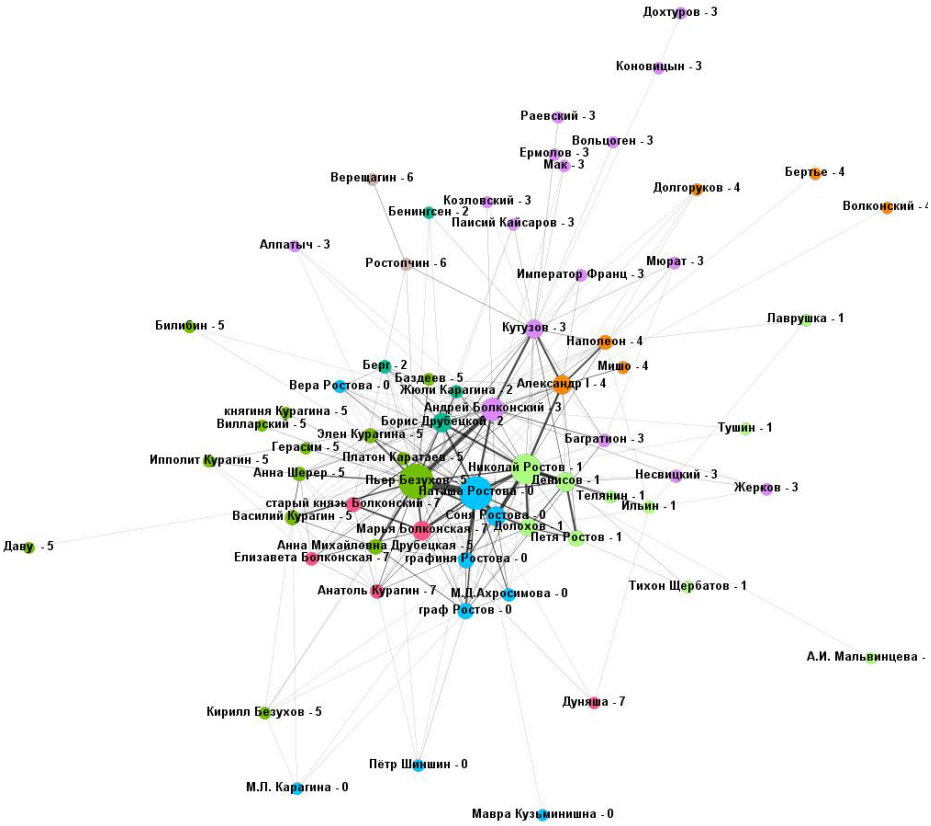

Fig. 5. Community detection in *War and Peace*. Node colors and numbers represent communities

of the plot. The results of such overlap are clearly visible in community #5. It unites such characters as Platon Karataev, Helene Kuragine, Anna Drubetskaya, freemason Villarsky, Kirill Bezukhov and general Davoust. Obviously, the only thing that connects this diverse set is their link to Pierre, but in each case the nature and circumstances of this connection are very different. Here we encounter a fundamental inability of the *static* network to encode the *dynamics* of the plot. One solution to this problem is to analyse network dynamically.

Dynamic network analysis

For dynamic network analysis we used the original split of the novel into 15 parts (often called 'books' in English translations) and two epilogues[1]. The limits of this paper do not permit us to analyse them all. Therefore we limit ourselves to the analysis of the first four parts of War and peace. This selection is enough to demonstrate that analysing novel by parts gives a clearer view on community structure and protagonist development. Fig. 5 presents network of the first part of the novel.

The most central character in this part of the novel is Pierre, which is an expected result. In Saint-Petersburg, Pierre is the catalyst of event at Anna Sherer's soiree and then it is through his eyes that we view Anatole's and Dolokhov's shenanigans; in Moscow, he is present at the Rostov's name day, and then he becomes the centre of intrigue around the legacy of his father, count Kirill Bezukhov.

As for community structure (color-coded in fig. 6), it is much clearer here than in the densely compressed network of the entire novel (fig. 3). Community #0 contains the younger generation of the Rostov family, as well as Vera's future husband Berg and Julie, whose brief period of supposed intimacy with Nikolai drives Sonya mad. Other communities include the older generation of Rostov family together with their Moscow circle (#2), the Bolkonsky family (#3, includes Hyppolite because of his persistent flirting with Lise), Anna Sherer's beau monde circle (#4). Anna Mikhailovna's frantic activity related to the Bezukhov legacy and to her own son's military career makes her the second most central character of this part, and results in formation of a separate 'Pierre plus the Drubetskoy family' pseudo-community.

Unlike the peaceful first part of *War and Peace*, the main events of the second part of the novel take place in the army during the War of the third coalition. This is visible in the network structure (fig. 7).

The two main groups are the army headquarters, where Andrey Bolkonsky serves as Kutuzov's aide-de-camp, and Nikolai Rostov's Pavlograd hussar regiment. This network is generally smaller and simpler in structure, reflecting the plain hierarchy and Spartan communicative austerity of military life depicted in the novel.

The third part of the novel is possibly the most diverse in terms of different chronotopes. Tolstoy portrays Russian army and military command in Austria, Rostov family in Moscow, Pierre, his marriage to Helene and his life with the Kuragin family in Saint-Petersburg, and Bolkonsky family in the Bald Hills. This diversity is obviously reflected in the network (fig. 8):

[1] In the version of the novel that has become canonical in Russia these parts are additionally grouped into four volumes (3-5-3-4). However, this division appeared only in the second edition of the novel circa 1873, and is not familiar to most English readers, who are more accustomed to the '15 books plus 2 epilogues' structure.

Fig. 6. Network of named characters in the first part (book one) of *War and Peace*

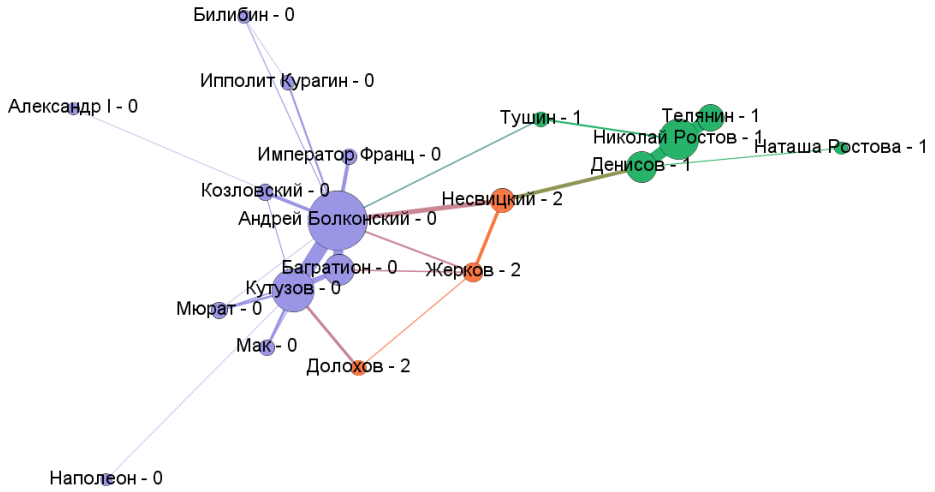

Fig. 7. Network of named characters in the second part (book two) of *War and Peace*

Community #0 is a reflection of the military and political subplot of this part; community #1 is made up of Anna Sherer, the Kuragin family and Pierre whom they effectively abducted into marriage; community #2 represents the Bald Hills cluster together with Anatole, due to his visit to Bolkonsky's in an attempt to marry princess Marya; community #3 is the 'Rostov world'.

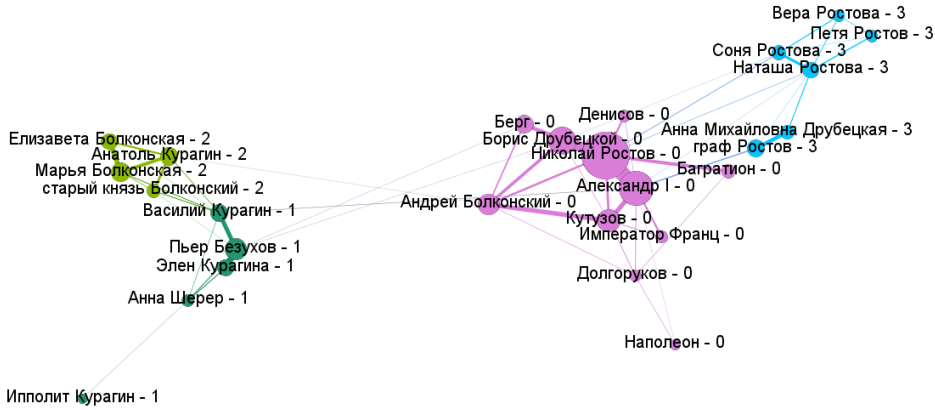

Fig. 8. Network of named characters in the third part (book three) of *War and Peace*

Fig. 9. Network of named characters in the fourth part (book four, or or the first part of the second volume in the canonical Russian version) of *War and Peace*

The fourth part of the novel (book four, or the first part of the second volume in the canonical Russian version) is largely focused on Nikolai Rostov's home leave in Moscow. This involves the development of his relations with Sonya, conflict over her with Dolokhov and a catastrophic card loss, Denisov's affection for Natasha (ending with his proposition being rejected), and Pierre's duel with Dolokhov, in which Nikolai took part as a second. Smaller fraction of part four is dedicated to the events at the Bald Hills, where the Bolkonsky family receives a note about prince Andrey's supposed death, but he turns up alive to witness his wife dying in childbirth. Both lines are visible in the network community structure (fig. 9):

While there is a lot more in the remaining networks for further parts of *War and Peace*, these four seem sufficient to demonstrate the potential of network analysis for detecting community structures in the novel and – speaking more broadly – for modelling the character system of a large fictional text.

Dense networks of peace

Our second hypothesis was that networks reflecting 'peaceful' parts of the novel differ in structure from those of the 'war' ones. We test it by calculating network metrics for each of the 15 main parts of the novel and the first epilogue and measuring their correlation with the share of the peaceful chapters in each part. The network metrics we apply include network density (see 'theoretical framework' above), network diameter, average node degree, average weighted node degree, average path length. Table 3 contains the Pearson's correlation coefficients for each metric.

Table 3. Correlations between network metrics and the shares of peaceful chapters

Network measure	Pearson's correlation coefficient with the share of peaceful chapters in part
Density	0.805
Diameter	-0.504
Average path length	-0.487
Average degree	0.663
Average weighted degree	0.72

Network density appears to have a strong positive correlation (0.8) with the 'peacefulness' parameter of the part of the novel, as well as the average weighted degree (0.72). This means that these parts tend to have more and stronger connections per one node, which indicates more intense social interactions. Negative correlation of diameter and average path length support the same hypothesis, as this means that segments describing war nodes are generally further from each other, i.e. the 'wartime' communities are sparser and less tight-knit.

Conclusion

We employed network analysis to model character system of War and Peace by Leo Tolstoy and used this formal abstraction to test certain assumptions (hypotheses) about the novel.

First, we tried to find out whether the network model of the novel's character space can be clustered into meaningful communities. The result we achieved here is largely positive. Even in the whole network that compresses a variety of data from all the 361 chapters of the novel we could automatically detect interpretable communities: the Rostov world, the military command, the Nikolai Rostov's circle. We also showed that analysing parts of the novel separately gives even better results when it comes to community detection, as the networks are not so overloaded with information from different parts of the plot.

Second, we attempted to measure the structural difference in networks depending on whether they describe war or peaceful events. This antithesis is crucial for Tolstoy's novel, and showing that this opposition is reflected on the level of character space structure could provide new insights on the great writer's literary technique. We used formal network measures which in certain ways reflect the connectedness and the intensity of interactions in networks. Some of these networks, such as density, were already reported [Trilcke et al. 2015a] to be a distinguishing feature for literary genres. Our results also show that 'peaceful' networks in War and Peace have a strong statistical tendency to be denser than the 'wartime' ones. They also have a bigger average weighted node degree and smaller diameter and average path length — all these things indicate more intense interactions and more interconnectedness in general.

Overall, both our experiments show that network analysis has potential as a method of digital literary research. Taking into account recent advances in natural language processing which allow greater and more precise operationalization and extraction of networks from unstructured texts, this opens up perspective for quantitative analysis of literature on a much larger scale.

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УДК 911.5/.9

Особенности создания сетевых исторических ГИС
(на примере проекта «III Государственная дума Российской империи»)

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Аннотация

Исследование предполагало создание геоинформационной системы (ГИС), которая позволила бы отобразить на карте Российской империи важнейшие характеристики избирательных процессов, сопровождавших выборы в Государственную думу Российской империи третьего созыва. Основным методом для получения пространственных данных об электоральных процессах стали методы пространственной визуализации и анализа на картографической основе. В частности, методы пространственного распределения и наложения данных по административно-территориальным единицам (губерниям) Российской империи, создания на основе этого карт и картограмм, отражающих соотношение показателей социально-экономического состояния и социокультурных характеристик и результатов электоральных процессов на уровне выборщиков и депутатов при выборах в Государственную думу третьего созыва. Геоинформационные системы позволяют установить территориальное распределение общественно-политических настроений и предпочтений, методов избирательной борьбы различных партий и политических сил России, выявить взаимосвязи политических групп в центре и на периферии империи, установить методы и степень влияния властей на ход и результаты выборов в III Думу.

Ключевые слова:

Российская империя, геоинформационные системы, электоральные процессы, Государственная дума.

Целью нашего проекта являлось ретроспективное изучение электоральных процессов методами геоинформационных систем. Исследование предполагало создание геоинформационной системы, которая позволила бы отобразить на карте Российской империи важнейшие характеристики избирательных процессов, сопровождавших выборы в Государственную думу Российской империи третьего созыва.

Проекция хода и результатов выборов на карту позволила по-новому охарактеризовать особенности политического процесса стабилизации государственной системы в эпоху Третьеиюньской монархии. Геоинформационные системы являются эффективным средством изучения источниковой базы электорального процесса, они позволяют установить территориальное распределение общественно-политических настроений и предпочтений, методов избирательной борьбы различных партий и политических сил России, выявить взаимосвязи политических групп в центре и на периферии империи, установить методы и степень влияния властей на ход и результаты выборов в III Думу.

В мировой историографии сложилось три больших направления применения исторических ГИС. К первому направлению относятся работы по аграрной истории и исторической экологии. Второе направление составляют исследования, связанные с так называемой геовизуализацией – реалистической реконструкцией исторического состояния окружающей среды определенной местности, причем это необязательно природный ландшафт. Третье направление состоит из инфраструктурных проектов, которые нацеливаются облегчить использование ГИС в историческом исследовании. Геоинформационные системы – это не просто инструмент, способный сделать изучение истории намного эффективнее; по мнению профессора университета Айдахо Оуэнса, ГИС способны расширить представления об историческом процессе вообще, приблизив его понимание к сформулированной в духе Ф. Броделя концепции глобальной, динамической, нелинейной исторической системы географических пространств, развивающихся во взаимосвязи друг с другом. Предметный анализ работ, выполненных с использованием геоинформационных технологий, показывает доминирование исследований в области взаимодействия человека и окружающей среды[1].

В настоящее время в международной и отечественной исследовательской практике в гуманитарной области изучение прошлого и настоящего избирательных процессов, а также их результатов осуществляется на основе междисциплинарных подходов и методов, политико-географического анализа, предусматривающих широкое применение геоинформационных систем и технологий для организации информации, ее обработки и визуализации (Н. Петров, В. Колосов, А. Перепечко, А. Титков)[2]. К примеру, в трудах по истории думских выборов в дореволюционной России идет речь о необходимости учета географических условий и особенностей, характеризующих эти процессы и их результаты (Н. Селунская и Р. Тоштендаль, И. Кирьянов, А. Титков)[3].

Для реализации настоящего проекта используются подходы и методы, опирающиеся на концепцию социально-политической структуры географического пространства, которая, в свою очередь, ориентирована на учет динамики, пространствен-

но-временных, территориальных и административно-территориальных факторов избирательных процессов, а также их результатов.

Многообразие и разнохарактерность мобилизованных сведений о выборном процессе потребовали глубокой проработки структуры базы данных, включая адаптацию форм многоуровневых группировок дореволюционной статистики к форматам реляционной базы данных. В силу значительного объема исходных данных потребовалась мобилизация группы студентов и аспирантов, которые в рамках работы над своими учебными проектами создали и заполнили базу данных, содержащую сведения о ходе выборов в III Государственную думу. В основу базы данных легло издание «Выборы в Государственную думу третьего созыва. Статистический отчет Особого делопроизводства»[4].

Статистические таблицы «Отчета» с данными о составе избирателей, ходе и результатах выборов были дополнены сведениями по Первой всеобщей переписи населения Российской империи 1897 года[5] и материалами текущей официальной статистики, содержащими сведения о социально-экономических, национальных, конфессиональных характеристиках населения, что позволило установить взаимосвязь хода выборов с различными социокультурными характеристиками регионов. Полученные данные позволяют установить степень зависимости электорального процесса в Государственную думу вообще и третьего созыва в частности от интегрированных показателей уровня модернизации и социокультурных характеристик населения разных регионов России.

Избирательные процессы разворачивались не только во времени, но и в пространстве. Для их отображения и временно-пространственной привязки материалы исторических исследований и источников были организованы в базу данных на основе электронных таблиц, затем интегрируемых в сетевой ГИС.

В геоинформационной системе были созданы необходимые для решения задач пространственного анализа карты и картограммы. В качестве карты-основы создана электронная карта Российской империи, разделенная на административно-территориальные единицы, соответствующие избирательным округам. Созданные карты и картограммы отражают территориальное распределение и локализацию по губерниям результатов выбора выборщиков и депутатов в Государственную думу третьего созыва, содержат ряд социокультурных показателей и позволяют путем пространственного анализа выявить наличие или отсутствие связей между ними.

Взаимосвязь между разделами сайта (mindmap), который содержит сетевую ГИС, представлена на рис. 1.

Система управления контентом (административная часть сайта) предоставляет возможность добавления, редактирования и удаления содержимого статических

Рис. 1. Mindmap

и динамических страниц. В качестве CMS была выбрана система WordPress, которая имеет стандартный для Windows интерфейс.

Система содержит три раздела: «О проекте» (информация об авторах проекта, публикациях), «Статистика», «Режим анализа».

В разделе «Статистика» в виде таблиц Exel выложены статистические сведения, относящиеся к процессу выборов в III Государственную думу, социально-экономические характеристики населения, сведения о депутатах, а также статистические сведения по крестьянскому движению начала XX века. Помимо этого, опубликована полная информация обо всех источниках, послуживших основой для базы данных.

В режиме анализа представлена картографическая часть ГИС. Раздел позволяет получить общие сведения о губерниях. Полученные таблицы разделены на более мелкие таблицы и сконвертированы в формат .csv для создания фильтров. Фильтры строятся автоматически по файлам .csv. Данные из .csv привязываются к каждой губернии. На основе данных из .csv строятся круговые графики (pie-charts) и таблицы с сортировкой по полям. Таблицы можно скачивать в формате Excel. Под картой представлена общая статистическая информация в табличном виде.

В данном разделе пользователь может произвести при помощи трех групп фильтров сортировку статистических данных:

- табличное представление данных;
- представление данных в виде piepchart;
- представление данных в виде разноцветных сравнительных интервалов.

Все три режима могут быть выведены одновременно. В каждом режиме система предлагает выбрать, какие показатели необходимо выводить и по каким губерниям необходимо выводить эти показатели. При отображении данных в табличном виде система позволяет выгрузить эти данные в Excel. Все данные сайта хранятся в структурированном виде под управлением реляционной СУБД. Картографические данные представлены в виде карты губерний, они хранятся в системе QGIS, из которой возможен экспорт.

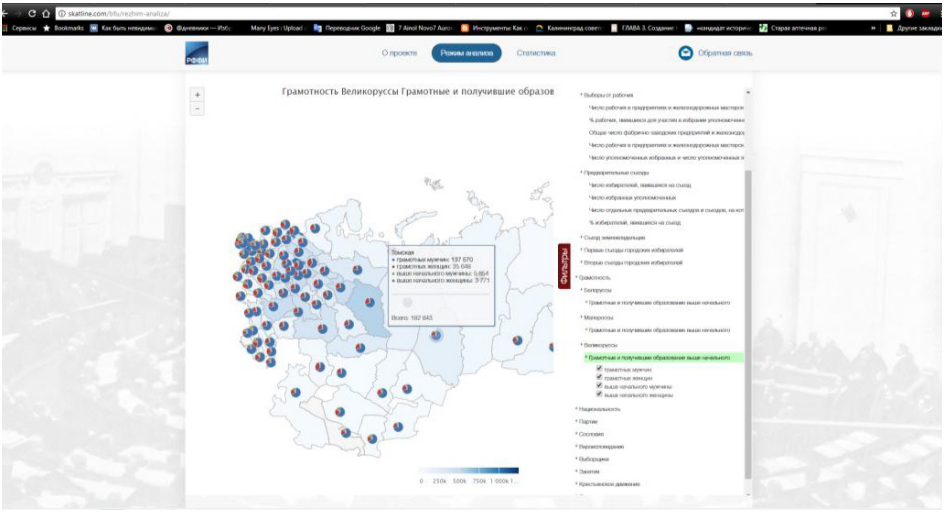

Рис. 2. ГИС «Выборы в III Государственную думу»

Для реализации верстки страниц и шаблонов используются языки HTML5 и CSS3, для генерации страниц – язык PHP, для реализации интерактивных элементов клиентской части – языки JavaScript (рис. 2).

Созданная для пространственной визуализации и анализа ГИС по выборам в Государственную думу Российской империи в начале XX века позволяет получать карты и картограммы, отображающие распределение по губерниям показателей по отдельным социокультурным характеристикам. Так, методом наложения табличных данных о грамотности населения по переписи 1897 года на карту-основу была получена карта распределения губерний Российской империи по уровню грамотности (рис. 3).

Полученная карта показывает локализацию уровней грамотности по губерниям. В частности, наиболее высоким уровнем грамотности характеризовались столичные губернии. Следующие два уровня представляли губернии Центральной России, протянувшиеся с севера на юг по московскому меридиану, а также крайние восточные европейские губернии – Вятская и Пермская. Между ними с расширением на северо-востоке и на юго-востоке располагались губернии следующего, более низкого уровня грамотности. Аналогичная, но более тонкая полоска подобных губерний лежит и с западной стороны. Далее на севере и на юге, на западе и востоке располагается достаточное количество губерний, представляющих еще более низкие уровни грамотности.

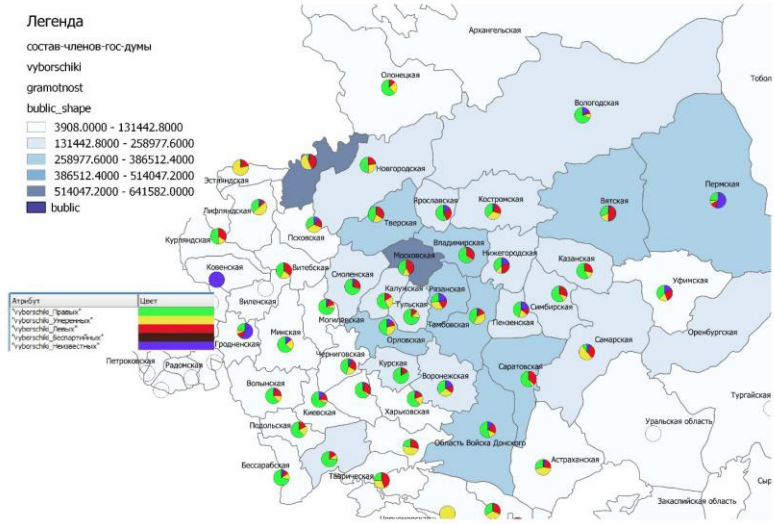

Рис. 3. Отношение между уровнем грамотности
и партийно-политическими результатами выбора выборщиков в губерниях

На основе карты распределения губерний по уровню грамотности была создана картограмма, отражающая по губерниям состав и структуру партийно-политических результатов выбора выборщиков. На картограмме достаточно хорошо видна невозможность установить какую-то закономерность или устойчивую тенденцию в отношении взаимосвязи уровня грамотности и партийно-политических результатов выбора выборщиков, что позволяет говорить о том, что, видимо, на эти результаты оказывали влияние какие-то иные, более значимые в данном случае факторы[6].

Созданная геоинформационная система, полученные с ее помощью карты и картограммы являются важнейшими результатами заключительного этапа проекта. Они позволяют пространственно визуализировать и анализировать функционирование Избирательного закона 3 июня 1907 года, отражают пространственное распределение губерний Европейской части Российской империи по характеристикам ряда социокультурных показателей и результатам выбора выборщиков и депутатов Государственной думы третьего созыва, создают возможность увидеть наличие или отсутствие связей между ними, основу для понимания и объяснения особенностей избирательных процессов на этом этапе парламентской истории России.

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Digital Humanities как коммуникативное практико-ориентированное виртуальное пространство проектов цифрового культурного наследия

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Аннотация

В данной статье на примере двух проектов, реализованных кафедрой информационных технологий в креативных и культурных индустриях Сибирского федерального университета, а также кафедрой графических технологий и Центром дизайна и мультимедиа Университета ИТМО, продемонстрированы возможности реализации серьезных научно-исследовательских и образовательных подходов в области Digital Humanities.

Ключевые слова:

мультимедиа, культура, Digital Humanities, виртуальная реальность.

Введение

Пул реализованных и реализуемых проектов в области сохранения культурного наследия с использованием передовых (на момент реализации проекта) технологий вкупе с программно-аппаратными комплексами достиг глобального уровня, поскольку концепция «превращения» абстракции в конкретный, пусть и виртуальный объект важна и визуально притягательна.

Реконструкция архитектурного сооружения или любого произведения из области культуры и искусства в объективной реальности неизбежно является своеобразным «новоделом», поскольку в силу вступает ряд объективных факторов, связан-

ных с материалами, финансированием проекта и т. д. В виртуальной реальности действуют иные законы, согласно которым адекватная виртуальная реконструкция, основанная на достоверных источниках и аналогиях (аутентичность объекта или процесса не менее 70 %), будет считаться уникальной, но эфемерной (поскольку ее не существует в объективной реальности).

Одним из ярких примеров, иллюстрирующих вышесказанное, является опыт кафедры информационных технологий в креативных и культурных индустриях Гуманитарного института Сибирского федерального университета, реализовавшей ряд проектов в области сохранения культурного наследия совместно с ведущими музеями Российской Федерации. Проекты были реализованы студентами данной кафедры в рамках практических занятий и подготовки дипломных работ под руководством квалифицированных научных работников.

В качестве примера подобного образовательного и научно-исследовательского подхода можно привести совместный проект с Русским музеем (Санкт-Петербург).

Студенты кафедры информационных технологий в креативных и культурных индустриях под руководством квалифицированных научных руководителей оцифровали ряд картин Русского музея в технологии gigapanoramic shooting, которая позволяет создавать гигапиксельные изображения с разрешением более одно-

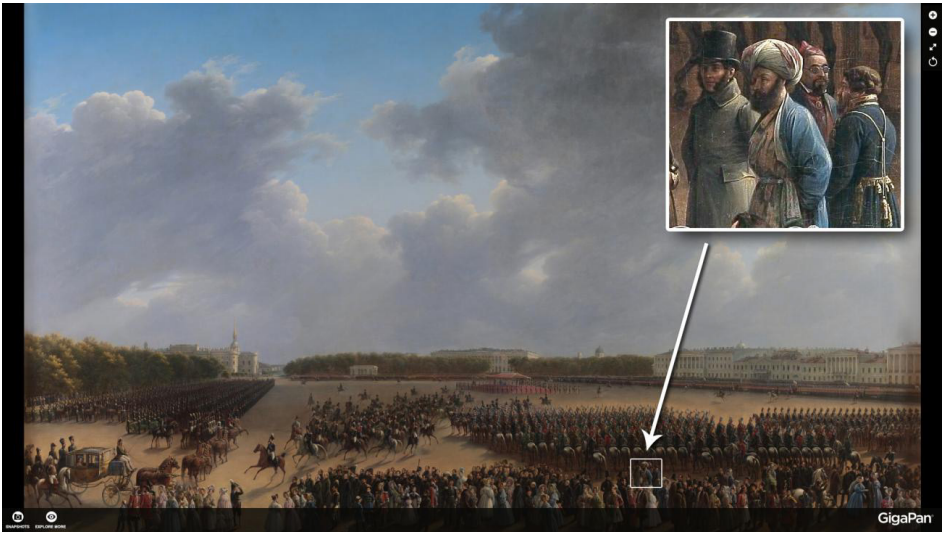

Рис. 1. Г.Г. Чернецов. Парад на Царицыном лугу 6 октября 1831 года.
Технология gigapanoramic shooting [2]

го миллиарда пикселей. Одной из подобных картин стала картина Г.Г. Чернецова «Парад на Царицыном лугу 6 октября 1831 года» (рис. 1) [1].

На полотне изображено около 300 знаменитых людей того времени, представляющих все социальные классы Российской империи (писателей, художников, ученых, военных, придворных и семью императора). Благодаря этому данное живописное произведение является своеобразным визуальным документом, иллюстрирующим конкретное историческое событие, а технология gigapanoramic shooting позволяет подробно изучить картину и провести соответствующую научно-исследовательскую работу.

Помимо размещения оцифрованного живописного произведения (с официального разрешения Государственного Русского музея) на специальном портале для просмотра изображений [2], созданных в технологии gigapanoramic shooting, данная работа была использована в проекте «Виртуальный Русский музей» (Русский музей. Дополненная реальность и Государственный Русский музей. Чернецов. Парад на Царицыном лугу в Петербурге) [3].

Виртуальная трехмерная реконструкция Феодоровского городка

Сотрудники кафедры графических технологий и Центра дизайна и мультимедиа Университета ИТМО совместно с кафедрой информационных систем в искусстве и гуманитарных науках Санкт-Петербургского государственного университета реализуют различные проекты в области Digital Humanities в сотрудничестве с различными научно-культурными учреждениями.

Одним из таких проектов стала виртуальная трехмерная реконструкция Феодоровского городка (рис. 3), включающая в себя как реконструкцию экстерьера комплекса зданий, так и наиболее репрезентативных интерьеров, в частности интерьера Трапезной палаты. Проект осуществляется совместно с Музеем-институтом семьи Рерихов и мастерской реставрации церковной живописи Академии художеств под руководством профессора А. Крылова.

Феодоровский городок был построен в Царском Селе по указу Николая II в 1913–1918 годах. Основной идеей создания этого уникального объекта стала визуализация истории русской архитектуры и искусства с XII по XVII век, для того чтобы жители Петербурга могли увидеть примеры подлинно русского стиля [4]. Русский стиль достиг наибольшего расцвета в императорской России, и его характерной особенностью являлся отказ от стилизации в пользу буквального копирования исторических памятников с опорой во многом на церковную архитектуру и живопись. В создании Феодоровского городка приняли участие члены Общества воз-

Рис. 3. Экстерьер Феодоровского городка

Рис. 4. Феодоровский городок. Резные ворота (результат фотограмметрии)

рождения художественной Руси, среди которых художники М. Врубель, С. Малютин, Н. Рерих, В. Васнецов и др. Главным архитектором проекта стал С. Кричинский.

В комплекс Феодоровского городка, представляющий собой замкнутый многоугольник, входили дома священников, дьяконов, выполненные в стилистике архитектуры Новгорода, Пскова и Костромы XVI–XVII веков, а также ворота, выполненные в стиле Владимиро-Суздальской архитектуры XII века (рис. 4). Центральным же зданием городка стала Трапезная палата, для которой были выбраны мотивы Теремного дворца и Грановитой палаты Московского Кремля. Трапезная палата предназначалась для деятельности «Общества возрождения художественной Руси», проведения различных концертов и выставок.

В рамках подготовки к виртуальной трехмерной реконструкции интерьера Трапезной палаты были тщательно проанализированы и изучены следующие материалы:
- архивные фотоизображения объекта;
- фотографии современного состояния объекта М. Капралова и Г. Майоровой;
- фильмография, предоставленная Музеем-институтом семьи Рерихов;
- прориси росписей интерьеров, разработка Царскосельской иконописной мастерской под руководством Г. Майоровой;
- архитектурные чертежи (фасады, планы, разрезы) и макет, предоставленные мастерской под руководством И. Шмелева, и т. д.

Также была проведена натурная фотосъемка экстерьера комплекса Феодоровского городка.

Процесс виртуальной реконструкции интерьера Трапезной палаты был разбит на пять этапов [4]:
- создание трехмерной модели потолка главного зала Трапезной палаты;
- создание трехмерной модели интерьера главного зала Трапезной палаты;
- создание разверток и текстур росписей потолка и стен главного зала;
- применение текстур и доработка интерьера Трапезной палаты;
- создание интерактивного приложения для просмотра виртуальной реконструкции интерьера Трапезной палаты.

Основным графическим редактором для реконструкции трапезной палаты Феодоровского городка стал Autodesk 3D Studio Max.

После проведенного анализа обмерных чертежей планов и разверток помещения возникла проблема несовпадения чертежей разных времен. Кроме того, авторские планы архитектора Кричинского не сохранились, а увидеть геометрию сводов было невозможно, поскольку потолок и перекрытия полностью разрушены. Тем не менее после сопоставления различных источников были созданы геометрически корректные развертки сводов потолка Трапезной палаты, по которым была реконструирована трехмерная модель (рис. 6).

Рис. 5. Интерьер Трапезной палаты, фотография 1917 года

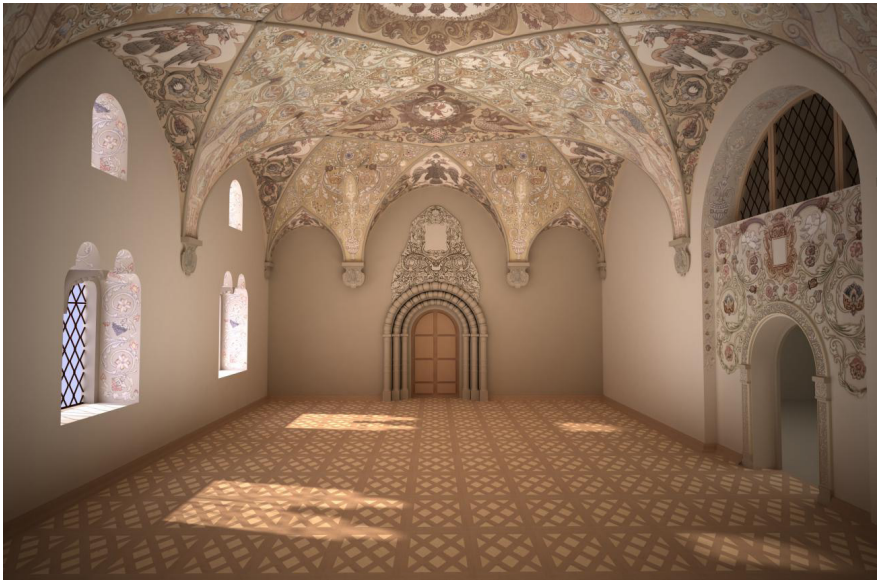

Рис. 6. Виртуальная трехмерная реконструкция Трапезной палаты Феодоровского городка

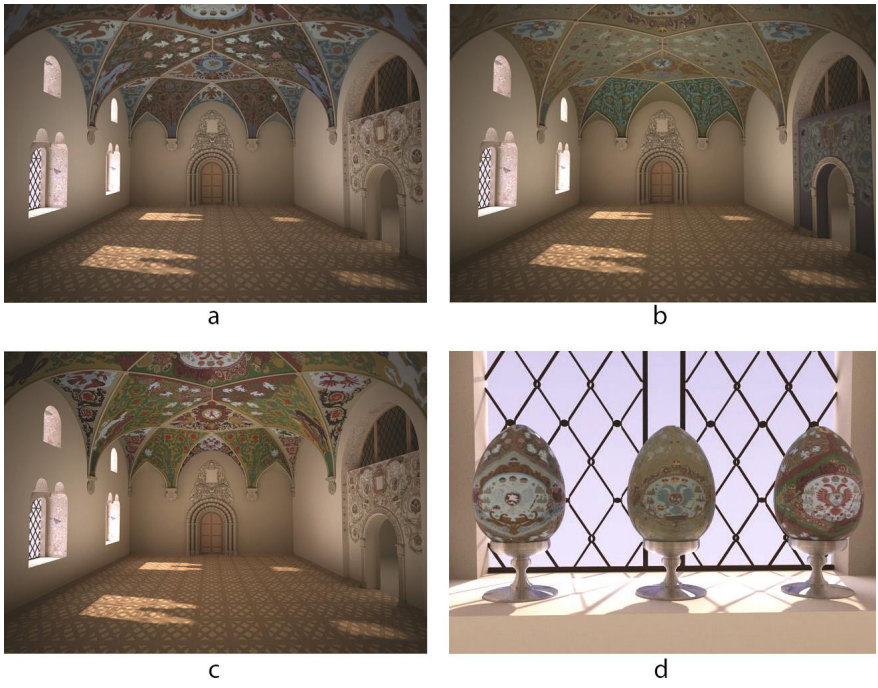

Рис. 7. Варианты цветового решения интерьера (a, b, c)
и интерактивные маркеры (d)

На основании полученных разверток студентами мастерской церковно-исторической живописи Санкт-Петербургской академии художеств под руководством А. Крылова были выполнены эскизы росписей сводов Трапезной палаты в различных колористических вариантах. Эскизы были использованы в качестве текстур потолка. Это позволило оценить конкретное колористическое и тональное решение непосредственно в реконструированном интерьере.

После виртуальной трехмерной реконструкции интерьера Трапезной палаты Феодоровского городка, а также создания эскизов росписей сводов в различных цветовых вариантах было создано интерактивное приложение с возможностью полного виртуального погружения в воссозданную среду.

Используя гарнитуру Samsung Gear VR, пользователь имеет возможность перемещаться внутри реконструированного интерьера, смотреть различные варианты эскизов росписей потолка, за что отвечают специальные маркеры, выполненные в форме пасхальных яиц (рис. 7) [6].

Заключение

Научно-исследовательская, образовательная и иные области Digital Humanities многогранны и позволяют создать целостную международную систему, основной целью которой является сохранение архитектурных и культурных сокровищ прошлого, а также последующая образовательная деятельность, основанная на результатах научных исследований.

В данной статье вышесказанное продемонстрировано на двух примерах – виртуальной оцифровке художественного произведения и виртуальной трехмерной реконструкции утраченного интерьера уникального исторического объекта.

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УДК 004.9

Digital Humanities – гибридный феномен: наука или технология?

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Аннотация

Вопросы, рассматриваемые в статье, актуальны на протяжении полувековой истории цифровых гуманитарных наук. Что такое DH? Это состоявшаяся наука со спектром критериев научной деятельности, понятийным аппаратом, характерными отличными чертами от других научных направлений? Это традиционно гуманитарные науки, рассматриваемые через призму компьютерных технологий? Или что-то иное? Стоит ли гуманитариям вести дискуссию относительно определения DH на протяжении стольких лет в постоянно меняющемся обществе и отношениях между машиной и человеком.

Ключевые слова:

Digital Humanities, цифровые гуманитарные науки, DH, цифровые технологии, гуманитарные науки.

Общество стремительно изменяется под воздействием глобального процесса информатизации, который интегрировал во все сферы исследовательской деятельности. Появилась безграничная возможность создания кросс-институциональных сетей, интерактивного представления информации и использования новых медиа в гуманитарных науках. «Цифровой поворот» [Гарскова 2014; Володин 2016] в гуманитарных исследованиях привел к появлению новой области – Digital Humanities (цифровые гуманитарные науки, далее – DH).

Историю англоязычного термина можно проследить с 1960-х годов во множестве научных публикаций [Busa 1980; Schreibman, S et al., 2008; McCarty 2005]. Digital Humanities является звеном цепочки: Computers and the humanities – Humanities computing – Humanities' information science – Digital Humanities [Гарскова 2014; Пруденко, Кузьмина 2012; Володин 2014]. Интерпретация названия сказывается и на реферируемых журналах Computers and the Humanities и ассоциации ALLC (Association for Literary and Linguistic Computing, 1978), ACH (Association for Computers and the Humanities, 1978).

На протяжении почти пятидесяти лет ведутся дискуссии на тему, что на самом деле представляет собой междисциплинарная область DH.

Рассуждая о сущности DH, можно сказать, что сколько исследователей, столько и мнений. Более 170 определений Digital Humanities представлено на площадке TAPoRwiki[1]. На начальном этапе цифровые гуманитарные науки не воспринимались отдельно от традиционных гуманитарных наук. Ансворт определяет цифровые гуманитарные науки как способ мышления, как набор логических критериев, как средство эффективного компьютерного процесса и как результат коммуникации между людьми. К тому же он отмечает, что применение компьютера в гуманитарном исследовании не присваивает ему статус цифрового [Unsworth 2000]. Смедт и Орланди поддерживают эту точку зрения. Смедт проводит аналогию с телескопом, который не использовался в научных целях, пока Галилей не применил его в своих научных изысканиях [De Smedt 2000]. Орланди утверждает, что цифровые методы обработки гуманитарного наследия появились задолго до появления компьютера [Orlandi 2002]. Паннапакер считает цифровую гуманитаристику новым модным направлением с большим количеством возможностей [Pannapacker 2009]. Альварадо относит цифровые гуманитарные науки к социальной, а не онтологической категории [Alvarado 2011]. Рокуэлл считает DH научным направлением, отмечая, что исследовательская деятельность должна выходить за рамки исследования текстов и их анализа, углубляясь в мультимедийную работу [Rockwell 2011]. По мнению Фреше, DH – это область применения новых технологий в качестве вспомогательного средства для поддержки гуманитарных наук, созданная для задач сохранения, реконструкции, передачи и интерпретирования знаний людей [Frischer 2009]. Сэмпл считает, что цифровые гуманитарные науки не столько создают, сколько делятся знаниями, интерпретируя их в новый мультимедийный и доступный формат. Российские исследователи также ведут дискуссии относительно самоопределения цифровой гуманитаристики [Можаева 2014; Гарскова 2014; Погорский 2014; Кижнер, Лаптева 2015].

Террас, Синкел и Гуглас высказывают мнение, что работа над созданием определений рискует стать помехой развитию дисциплины и тем самым ограничит спектр исследовательской деятельности [Terras 2006; Sinclar, Gouglas 2002].

Вернемся к тому, что о DH написано достаточно много, но до сих пор нет четкого определения. Почему возникает потребность в определении этой научной области?

Во-первых, определив место в научном пространстве, исследователи этой области смогут объяснить научному сообществу, чем и для чего они занимаются, тем самым

[1] http://www.artsrn.ualberta.ca/taporwiki/index.php/How_do_you_define_Humanities_Computing_/_Digital_Humanities%3F.

привлекут сотрудников для междисциплинарной работы, а студентов и аспирантов заинтересуют идеями научных изысканий.

Во-вторых, финансирующим организациям станут понятны инвестиционные вложения, которые могут привести к поддержке проектов, открытию новой учебной программы в университетах и центрах DH.

В-третьих, станет возможным ограничить круг специалистов данной области от тех, кто представляет результаты цифровых гуманитарных исследований, которые не относятся к этой области.

В-четвертых, любая претендующая на статус научной дисциплины область знания нуждается в определенном понятийном аппарате. Создавая новую парадигму образовательной дисциплины, необходимо начинать с определения. «Разнобой в терминах – это то самое «смешение языков», помешавшее строителям Вавилонской башни. Эффективная совместная работа возможна только тогда, когда есть единое понимание базовых оснований» [Гальетов 2008]. Считаю уместным ввести в научную практику следующее определение: **Digital Humanities – междисциплинарное, гибридное направление, рассматривающее традиционные гуманитарные науки с помощью цифровых и информационно-коммуникативных технологий.**

Так ли это всё на самом деле? Digital Humanities – это что-то новое или мы давно это изучаем? Это наука, дисциплина или всего лишь прикладная методология?

Независимо от бурного развития за последнее десятилетие сферы DH, весьма проблематично охарактеризовать направление как научное в связи с отсутствием четких критериев. Общеизвестно, что наука – это область человеческой деятельности, направленная на выработку и систематизацию объективных знаний об окружающей действительности.

Поскольку наука в целом и научное исследование в частности представляют собой особую целенаправленную деятельность по производству новых, надежно обоснованных знаний, они должны располагать своими специфическими методами, средствами и критериями познания. Именно эти особенности отличают науку от ненаучных его форм.

Сегодня в области науки можно выделить следующие аспекты:
- наука как результат – получение научных знаний;
- наука как процесс – сама научная деятельность, процесс познания;
- наука как социальный институт – совокупность научных учреждений, сообщество ученых.

Можно также обозначить характерные черты науки: рациональность, достоверность, критичность, систематичность, универсальность и общепринятый категориальный аппарат.

Современную науку, во всем многообразии дисциплин, можно разделить на две сферы: фундаментальные и прикладные науки. Фундаментальные науки занимаются изучением объективных законов мира – как они существуют «сами по себе», безотносительно к интересам и потребностям человека. Прикладные науки нацелены на разработку способов применения полученных фундаментальной наукой объективных знаний для удовлетворения потребностей и интересов людей.

Попытаемся «уложить» понятие DH в вышеобозначенную структурно-логическую схему науки.

Анализ определений цифровых гуманитарных наук, фактологической информации о данном исследовательском направлении позволяет выделить в DH определенные черты науки, а не простого накопления знаний. Проектирование модели исследования, объективность проводимых исследований, создание научной методологии, системы методов, способов и инструментов существует в научном подходе направления цифровых гуманитарных наук. И лишь одна черта DH не укладывается в данную схему – главная цель всего научного процесса – познание. Познание, а не стремление получить конкретный материальный и практический результат. И тогда, очевидно, мы имеем дело с технологией, а не наукой. Либо, по меньшей мере, с наукой, но не фундаментальной, а прикладной.

Следует отметить, что технология зависима от науки, поскольку использует научные знания в своих целях, а так как сегодняшние технологические процессы достаточно сложны, то дальнейшее развитие технологии невозможно без научного прогресса.

Термин «технология» прочно вошел в профессиональную лексику сферы DH. Несмотря на то что существуют разные трактовки этого понятия, есть ряд и объединяющих позиций. Технология как совокупность методов, форм и средств (набор инструментов) создается с целью применения в других областях деятельности. Говоря о структуре технологии, следует отметить, что составными ее элементами должны служить: концептуальность, системность, управляемость, эффективность и воспроизводимость этой технологии в других однотипных учреждениях и другими субъектами.

DH как технология, с совокупностью методик оцифровки, работы с архивными данными, дигитализацией, открытыми данными, утвердилась в исследовательской практике.

Таким образом, можно утверждать, что цифровые гуманитарные науки как совокупность надежных технологий помогают делать в гуманитарных исследованиях

более точные выводы и выявлять новые закономерности. Развитие Digital Humanities показывает, что информатизация способствует междисциплинарному синтезу гуманитарных наук и цифровых практик. На наш взгляд, DH находится на этапе становления в качестве научного направления. Цифровые гуманитарные науки не столько создают, сколько делятся знаниями, по мнению Марка Семпла. На базе фундаментальных наук происходит интерпретация знаний и представление их в новом – медийном – образе.

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Монголо-бурятский орнамент на сайте monornament.ru[1]

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Аннотация

Чтобы изучить народный орнамент, нужно воспользоваться книгами, пособиями и личным опытом мастеров. При этом книг и пособий, например, в Бурятии издается недостаточно, они являются редкостью, их трудно найти. Встретиться с искусным мастером часто также затруднительно. Поэтому мы предлагаем воспользоваться интерактивной базой данных орнаментов (БДО) бурят и монголов, которая содержит изображения и многоаспектные описания узоров. Кроме того, на сайте в онлайн-режиме возможно создание собственного образца орнаментального панно.

Ключевые слова:

информационный ресурс, база данных орнаментов, онлайн-конструктор орнаментов.

Введение

Монголоязычные народы, к которым относятся монголы, буряты и калмыки, имеют близкие культурные традиции, похожие по мотивам орнаменты. Однако отличия в узорах имеются даже в образцах восточных и западных бурят, что обусловлено как разницей природных условий проживания, так и влиянием соседствующих народов. Монгольский узор, таким образом, получается довольно неоднозначным термином. Мы будем подразумевать под ним характерные образцы бурятских и монгольских орнаментов.

О происхождении и развитии бурятского орнамента достаточно подробно написано в монографии Е.А. Баторовой [1], обобщающей труды предшественников. Образцы узоров бурят представлены в работах П.П. Хороших [2–4], Ф.И. Балдаева [5], Е.Б. Батоцыреновой [6], альбоме художника Л. Доржиева [7] и др. Мотивы и композиции монгольского орнамента изучались нами по книгам Л. Батчулууна

[1] Работа выполнена при поддержке гранта РФФИ № 15-47-04328.

[8], Ц. Ядамжава [9], Б. Болда [10], альбому рисунков художника Манибадара [11], предметам из музейных коллекций.

Для удобства мы используем следующие определения: орнамент или композиция орнамента – это узор, основанный на повторе и чередовании составляющих его мотивов. Мотив – устойчивое изображение, состоящее из двух или более одинаковых или разных элементов, структурно упорядоченное и обладающее определенной семантикой. Элемент – составляющая часть мотива.

Классификация орнаментов

Для заполнения БДО нами была создана расширенная многоаспектная классификация. Единая классификация до сих пор не выработана ни в России, ни в других странах. Специалисты обычно пользуются различными системами классификации орнаментов в зависимости от целей конкретной работы. Например, в 70-е годы XX века в Нидерландах в качестве стандартной классификации для коллекций изображений и текстов была разработана система Iconclass [12]. Она предназначалась для создания очень больших баз данных, содержащих конкретные детали, предметы или другие общие сведения о музейных и подобных им коллекциях. В настоящее время она содержит более 28 000 уникальных понятий (параметров классификации), часть из которых относится непосредственно к орнаменту. По информации создателей, систему Iconclass используют несколько крупных европейских музеев. В 2016 году начался перевод этой системы на русский язык с целью описания частной коллекции ранних немецкой и нидерландской гравюр в Москве. Эта система может быть очень полезна для иконографических исследований различных видов искусства в музеях и частных коллекциях, включая как западное, так и восточнохристианское искусство. Однако, на наш взгляд, эта классификация чрезвычайно громоздка и неудобна для описания сравнительно небольших коллекций бурят-монгольских узоров.

Заметим, что для сайтов библиотек, архивов, музеев, представляющих искусство разных народов из своих запасов, характерна ситуация с полным отсутствием или весьма кратким описанием орнаментального декора. По нашему мнению, орнамент, как самостоятельный вид декоративного искусства, заслуживает детальной систематизации и описания.

Мы разработали собственную, достаточно подробную систему описания орнаментальных мотивов и композиций примерно по двадцати параметрам, которые имеют различное количество значений; таким образом, классификационные характеристики мотивов и композиций отображаются более чем в 50 полях [13]. Классификатор орнаментальных изображений в последней редакции дополнен несколькими новыми параметрами, например «коллекцией для композиций».

Вид мотива как изображения, материал, на который наносится узор, и тип симметрии – это традиционно используемые характеристики. Около двадцати позиций были добавлены для составления более полного описания мотивов и композиций. Эти параметры несколько отличаются друг от друга. Например, тип симметрии для мотивов указывает собственную симметрию фигуры – зеркальную, поворотную, зеркально-поворотную, а для композиций тот же параметр обозначает симметрии розеток, бордюров и узоров обоев. Вид образующих линий, – т. е. состоит он из прямолинейных или криволинейных элементов, указывается только для мотивов. Для композиций в виде прямоугольного или кругового панно геометрическое расположение мотива важно обозначить: в центре, в рамке или иное. Здесь также используется параметр «сочетание мотивов», в котором выделено четыре пункта: переплетение, обособление, включение и чередование.

Установление времени и места возникновения, а также авторства для мотива проблематично; для композиций эти данные выявить проще. Заполнение таблиц с характеристиками – процесс трудоемкий и требующий знания истории, этнографии, искусствоведения, теории симметрии и математики, а также умения использовать графические пакеты программ для редактирования изображений.

Представление БДО в сети Интернет

В последние десятилетия становится все более актуальным размещение электронных архивов и баз данных в открытом доступе в сети Интернет. Этот способ позволяет преодолеть проблему физического устаревания базы данных, а кроме того, реализация в виде открытого информационного ресурса предоставляет возможность получить информацию широкому кругу лиц.

С учетом современных требований принято решение разработать ресурс в виде интернет-портала. Для реализации проекта выбран инструментарий, включающий систему управления базами данных (СУБД) MySQL и фреймворк Yii2. Создаваемая онлайновая версия БДО будет хранить не менее 3000 изображений с подробными описаниями в соответствии с разработанной классификацией.

При формировании открытого веб-ресурса целесообразно размещать изображения на сервере и предоставлять их по ссылкам, тем самым разгружая СУБД. Авторами проанализированы стандартные системы управления сайтом (CMS). CMS предназначены для создания стандартных информационных ресурсов, тогда как специфика разрабатываемого проекта состоит в необходимости расположить на сайте базу данных орнаментов. В связи с этим принято решение использовать Content Manager Framework (CMF), это CMS с большим количеством возможностей.

Для реализации проекта командой разработчиков выбрана программная платформа Yii2. Данный фреймворк является программным решением с открытым кодом, он

широко распространен среди разработчиков. Имеется сообщество, которое постоянно развивает сам фреймворк и модули для него. Одним из таких модулей является EasyYii, который реализует функционал стандартной CMS.

Основные плюсы выбранного решения:
- гибкость: фреймворк позволяет создавать приложения любой сложности;
- функциональность: EasyYii содержит все необходимые для стандартного ресурса функции;
- стандартные системные требования для большинства компаний (хостеров), предоставляющих место на своих серверах под размещение веб-сайтов.

Для осуществления импорта базы данных в формат СУБД MySQL были произведены следующие изменения:
- изображения выгружены и сохранены в виде файлов на сервере в форматах растровой графики (jpeg, bmp);
- соответствующие им описания записаны в отдельные связанные таблицы;
- изменена структура базы данных (добавлены справочники, произведена оптимизация таблиц базы данных).
- изображения преобразованы в новые форматы (png, svg).

Структура сайта

В ходе проектирования портала были выделены основные модули приложения.

1. Информационный блок. Модуль реализует задачи стандартного веб-сайта, отображая информационные материалы о проекте, аннотации опубликованных статей по теме проекта, полезные ссылки на сайты по орнаментам, контакты.

2. Электронная база данных орнаментов. Модуль предоставляет возможность публикации графических изображений и сопроводительных текстовых материалов о мотивах и композициях орнаментов, гибкого поиска по БДО, добавления и редактирования контента.

БДО организована так, что возможен просмотр комплексов или мотивов и свободный переход между ними. Изображения мотивов с названиями на русском, бурятском (тувинском) и английском языках выводятся на экран одновременно по двенадцать, их можно отсортировать по алфавиту или дате внесения в БДО, а также воспользоваться фильтром по любому параметру. Мотивы можно находить, пролистывая страницы или введя название (начальные буквы) в строку поиска. При выборе какого-либо мотива осуществляется переход на страницу с композициями, содержащими этот мотив, там приводится полное описание мотива (по всем его характеристикам). Рядом с изображением каждой композиции представлено ее краткое описание, для просмотра полной информации необходимо перейти даль-

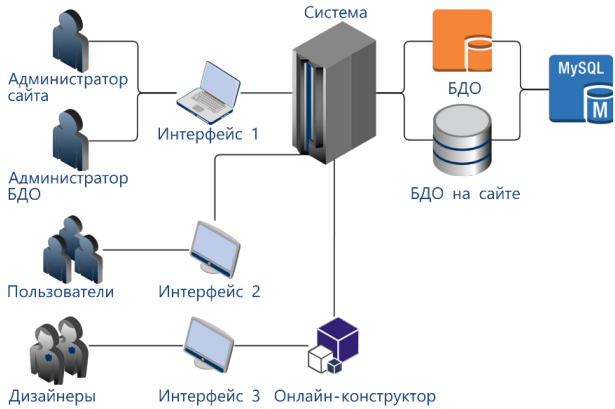

Рис. 1. Общая архитектура системы

ше на страницу выбранной композиции. На конец 2017 года БДО содержит 127 мотивов и около 2000 композиций орнаментов бурят, монголов и тувинцев.

3. Конструктор орнаментов. Задачей данного модуля является предоставление возможности создания в онлайн-режиме орнаментов в виде панно из составных частей, также хранящихся в базе данных.

Панно – это орнамент, в котором имеется явно выраженный центр, угловые заполнения и рамка. Панно может иметь форму круга, прямоугольника, восьмиугольника и т. д. При внесении узора в БДО указывается, является ли композиция угловым заполнением, центральной частью или бордюром, из которого можно сформировать рамку для панно. На сайте реализован вариант онлайн-создания прямоугольного панно, две простые рамки можно преобразовать из прямоугольных в круговые, в дальнейшем возможно расширение функционала геометрического конструктора для других форм. Конструктор реализован в векторном формате SVG, что обеспечивает более простое масштабирование частей узора и упрощает дальнейшую работу с рисунком после скачивания. Архитектура системы показана на рис. 1.

Система сбора данных

Электронная база данных орнаментов представляет собой веб-ресурс и, как было отмечено выше, сайт создан с использованием сборки EasyYii для фреймворка Yii2, применение которой позволяет быстро реализовать публичную часть. Кроме того, EasyYii уже содержит реализацию систем публикации материалов на сайте, порядок авторизации и аутентификации.

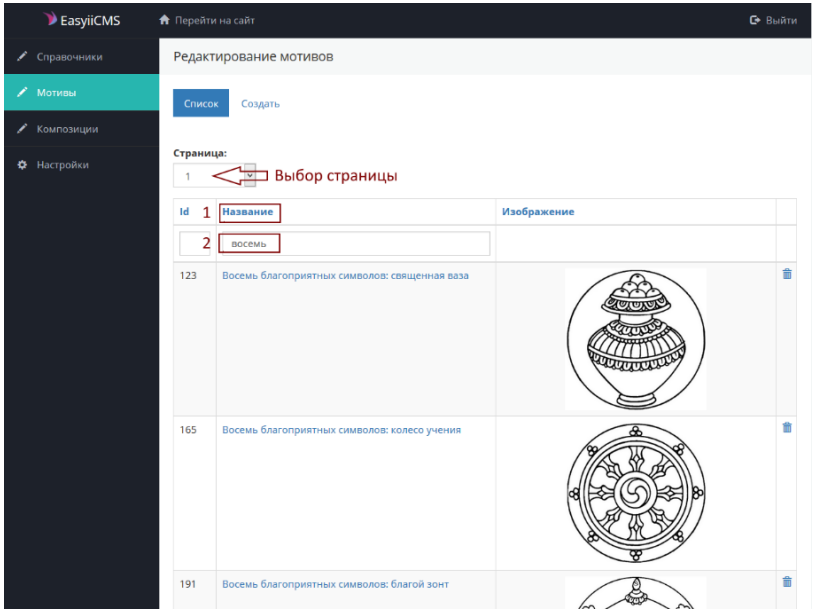

Рис. 2. Панель управления мотивами

Для описываемого проекта были созданы удобные модули для работы с мотивами и композициями, которые позволяют осуществлять добавление, удаление и редактирование мотивов и композиций соответственно.

Скриншот панели управления мотивами представлен на рис. 2. На этой странице выводится список мотивов с указанием его ID, названия и изображения размером 500x500 px. При нажатии на название мотива пользователь переходит на страницу его редактирования, для каждого мотива существует возможность удаления. Кроме того, для удобства реализована сортировка названий мотивов по алфавиту (нажатием на область 1) и поиск по названию или по части названия, которые можно ввести в поле 2. На странице располагается по 10 мотивов, навигация по страницам осуществляется путем указания номера страницы. Окно выбора страницы расположено наверху панели управления.

Рассмотрим более подробно устройство страницы «Редактирование мотива» (рис. 3). При редактировании или создании мотива администратор должен заполнить форму, в которой автоматически показываются все параметры мотива. В соответствии с разработанной авторами классификацией форма содержит 23 поля. Название мотивов дается на трех языках – русском, бурятском и английском. Возможно,

будет добавлено название на монгольском языке, а при увеличении количества описываемых народных орнаментов – и на языках добавляемых народов. Так, уже добавлено поле «Тувинский язык» для соответствующих узоров. Изображение большинства мотивов представлено в виде контура, т. е. мы сознательно выбираем из множества вариантов наиболее простой. Только более сложные мотивы, например слон, передаются штриховым рисунком. В качестве источника изображения приводится название печатного издания, из которого взят образец.

Множество параметров для удобства объединены в группы. Их выбор осуществляется с помощью простановки флажков, что значительно ускоряет заполнение формы. Для ввода информации о дате и источнике происхождения, виде симметрии и символике мотива предусмотрены текстовые поля. Дополнительная информация отображается также в текстовом поле «Примечания». В настоящий момент заполнены данные по 114 известным монголо-бурятским мотивам и добавлены 13 тувинских мотивов, некоторые мотивы используются и бурятским, и тувинским народами. Вид симметрии мотива указывается двойным обозначением – по Шубникову [14] и в скобках – международные символы по Яблану [15].

Наибольшие затруднения вызывает заполнение двух полей: «Дата» и «Степень сложности», так как они требуют специальных дополнительных исследований. Происхождение множества мотивов датируется III–II вв. до н. э., другие возникли позже; мы считаем время создания мотива одной из важнейших характеристик, которая будет впоследствии установлена и зафиксирована в создаваемой базе данных.

Вычисление степени сложности изображения необходимо для формализации изучения орнаментов, введения в эту область не только описательных, но и численных математических характеристик. К сожалению, пока единой методики для вычисления не существует, хотя примеры расчетов имеются [16; 17].

Окно формы можно масштабировать, увеличивая изображение для удобства заполнения. В этом случае на экране форма полностью не помещается, но вполне хватает двух размеров экрана. Очень удобно организована кнопка для сохранения данных с мини-изображением узора (внизу справа), которая при любых перемещениях по экрану остается видимой. На рис. 3 показано три таких кнопки, которые были видны при увеличении.

При добавлении нового мотива или композиции все необходимые атрибуты формы уже отмечены флажками. Специалисту, который вносит новые значения в базу данных, необходимо скорректировать форму, убрав лишние отметки. Данный подход позволяет ускорить заполнение базы данных.

Панель управления композициями спроектирована аналогичным образом, содержит 16 характеристик в 52 полях. Здесь появилось поле «Автор», где по возмож-

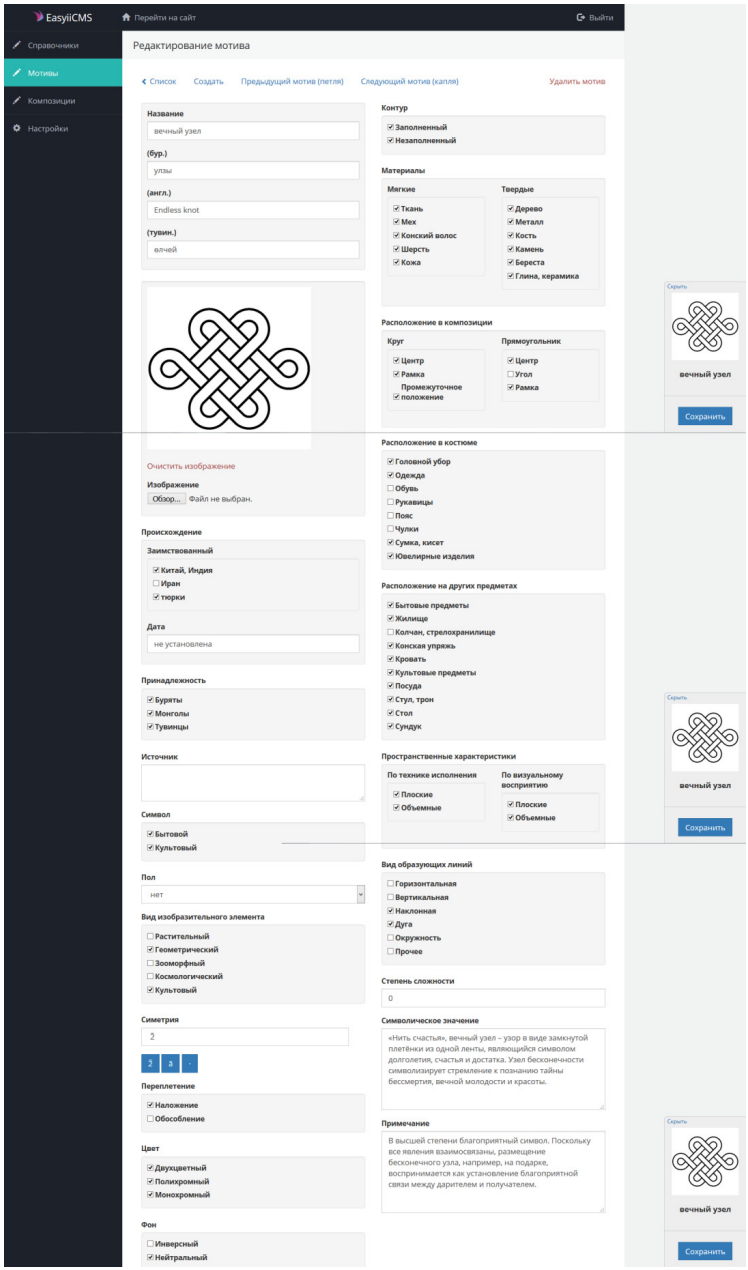

Рис. 3. Панель «Редактирование мотива»

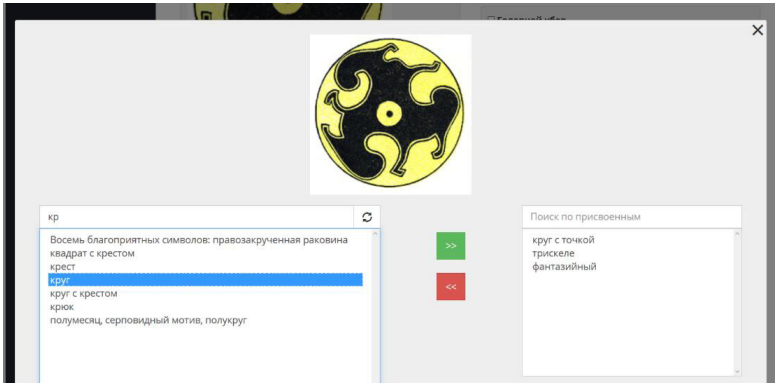

Рис. 4. Пример выбора мотивов, составляющих композицию

ности будут указываться мастера и художники, создававшие образцы. Так как композиции чаще всего не имеют оригинальных наименований, нами используется проставленные через дефис: аббревиатура названия источника или начальные буквы фамилии автора, год издания, номер страницы и номер изображения, если их на странице несколько. Например, один из бордюров из альбома «Бурятский народный орнамент» [3] обозначен как БНО-1972-55-2, а розетка из книги Ц. Ядамжава (1985 год издания [4]) названа Я-1985-47-8. Кроме источника, для части композиций указывается коллекция, например, узоры из коллекции П.П. Хороших опубликованы в нескольких книгах, но имеется возможность просмотреть их все, выбрав из списка при поиске это имя.

Для удобства указания мотивов, составляющих композицию, создано отдельное всплывающее окно с увеличенным изображением узора и списком всех мотивов, из которого легко осуществляется выбор нужных названий (рис. 4).

Композиций, включающих один, а чаще несколько мотивов, многие тысячи. В БДО отредактировано содержимое, которое было извлечено из предыдущей версии базы данных, параллельно вводятся новые изображения и их характеристики. Объем БДО будет превышать 3000 орнаментальных композиций.

Пример композиции со всеми характеристиками показан на рис. 5. Этот узор состоит из двух мотивов, один из которых – «полоса», а не «зигзаг», так как прорисованы вывязанные петли, и, по существу, они образуют полосы разной ширины. Второй мотив «фантазийный», то есть это изображение, придуманное мастером (художником, дизайнером). Чаще всего используется как дополнительный элемент орнамента, не относится к традиционным мотивам. Конкретного рисунка у мотива нет, он применяется в случае непонятного на данный момент изображения. В случае

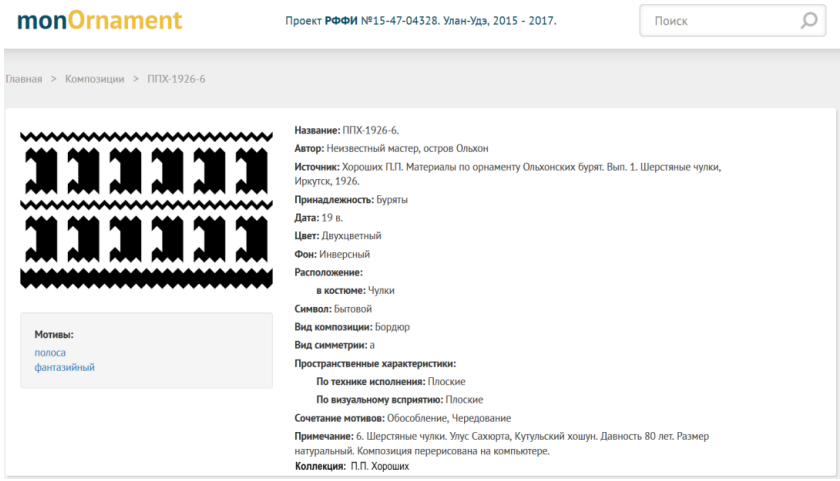

Рис. 5. Пример композиции с описанием по 16 параметрам классификации

дальнейших уточнений и появления новых сведений в базу могут быть добавлены новые мотивы.

Конструктор

Классифицируя композиции по виду изображения, мы выделяем уголки, бордюры, розетки, панно и сетчатые узоры. В разделе сайта «Конструктор» из уголков, бордюров и розеток предусмотрено формирование орнаментов в виде панно в режиме реального времени. Так как в БДО используется растровый формат, а в Конструкторе – векторный, прямые соответствия изображений отсутствуют. Прямоугольное панно обычно включает в себя центральную часть (в виде розетки), симметрично расположенные четыре угловых фигуры и рамку в виде замкнутого бордюра. Простейшая рамка состоит из одной или нескольких полос. Более сложные рамки представляют собой орнаментальные бордюры, состыкованные определенным образом, с аккуратной проработкой углов.

На рис. 6. показан пример панно, сформированный в онлайн-конструкторе из центра № 18, уголка № 2 и рамки № 4. Выбранные образцы центральной розетки и уголков могут масштабироваться, уголки автоматически симметрируются. Уголки могут также сдвигаться по горизонтали и вертикали, формируя необходимые пропорции сторон прямоугольника и регулируя отступы от рамки. Доступен выбор пропорций из различных предлагаемых соотношений, в том числе с учетом золо-

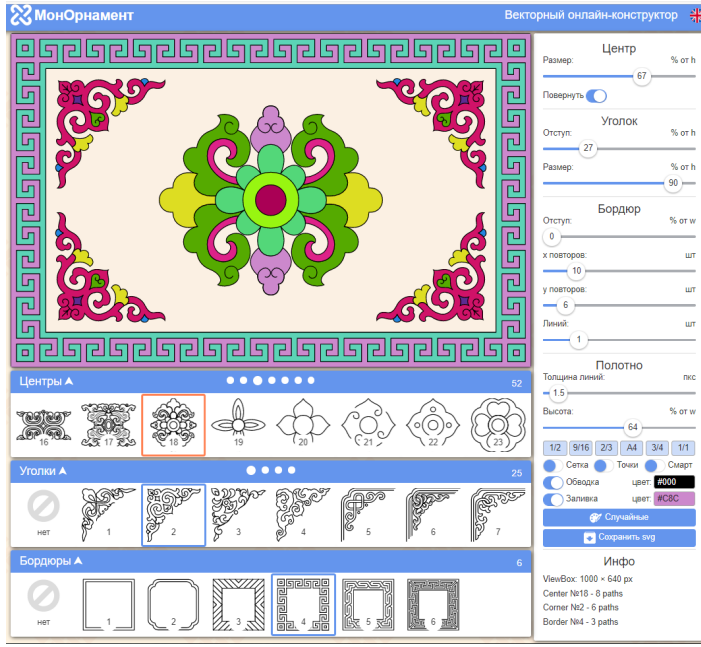

Рис 6. Онлайн-конструктор прямоугольных панно

того сечения. В данном примере соотношение сторон зависит от числа повторов Т-образных элементов рамки по вертикали и горизонтали и равно 6/10. Раскрашивание панно происходит случайным образом выбранными цветами, которые можно изменить, используя прилагаемую палитру цветов.

Если в образце выбранного уголка присутствуют незамкнутые полосы, то они автоматически продлеваются до середины прямоугольника, образуя замкнутый контур, в этом случае можно обойтись без дополнительной рамки. Создание отдельных образцов бордюров для рамок – это специфическая и непростая задача. Пока предлагаются две простые рамки в виде полос, количество которых можно изменять от 1 до 5, и четыре характерные узорные прямоугольные рамки. Квадратную рамку можно преобразовать в окружность, создав тем самым панно в круге.

Пользователь, имея 50 центральных элементов, 25 образцов уголков и 6 видов рамок, может создать более 7000 разнообразных вариантов панно (без учета масштабирования и прочих редакторских правок) и затем сохранить образец в векторном формате для дальнейшего использования в своем творчестве.

Выводы

Таким образом, в работе рассмотрен опыт разработки интернет-портала monornament.ru [18]. На данный момент прототип сайта реализован и размещен в открытом доступе в сети Интернет. Авторами переработана и дополнена классификация орнаментов, на основании которой созданы шаблоны описаний мотивов и композиций для представления на портале. Разработан прототип конструктора орнаментальных панно, позволяющий быстро создать вариант узора, приемлемый для украшения различных прямоугольных поверхностей: открыток, грамот, упаковочных коробок, столов, сундуков и т. п. Используется дружественный интерфейс, и сама база данных орнаментов стала более современной, удобной и насыщенной информацией.

Размещение электронной базы данных, посвященной традиционному орнаменту, в онлайн-доступе позволяет обеспечить широкий доступ заинтересованных лиц к важной части национального культурного наследия бурят и монголов, изучать, сохранять и развивать народные традиции. Проект может быть полезен искусствоведам, культурологам, этнографам, мастерам художественных промыслов, школьникам и студентам, учащимся художественных школ, дизайнерам мебели, одежды, посуды, ювелирам и архитекторам.

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УДК 004.9

Digital Humanities в структуре гуманитарных наук

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Аннотация

Предпринята попытка философского анализа места цифровых технологий в структуре гуманитарных наук, а также Digital Humanities в целом. Рассмотрены варианты изменения структуры гуманитарного знания посредством воздействия инструментария Digital Humanities.

Ключевые слова:

Digital Humanities, междисциплинарные исследования, цифровые гуманитарные науки, структура гуманитарного знания.

Введение в проблему исследования

Digital Humanities на протяжении уже почти полувека доказывает, что действительно является отдельной областью исследования. И имеет безусловные основания для этого: завершен и представлен ряд убедительных проектов в области лингвистики, истории, музыки, искусствоведения, реализованных с использованием цифрового инструментария; сформировано научное сообщество Digital Humanities, которое в рамках регулярно проводимых конференций и семинаров представляет результаты своих исследований; обсуждается становление Digital Humanities как учебной дисциплины [6].

Таллер Манфред, профессор Кельнского университета, в 2012 году предпринял попытку анализа дискуссий вокруг Digital Humanities, выделяя между тем опасности развития данной междисциплинарной области: акцент на инфраструктуру для Digital Humanities может затенять тот факт, что исследования в конечном счете обусловлены аналитическими методами и инструментами, а не только обеспечением необходимыми данными или публикацией исследовательского инструментария; IT может поддерживать гуманитарные науки во многих формах и национальных традициях, что, однако, не должно закрывать более широкого взгляда на возможности Digital Humanities; надвигающаяся «мобильная революция» может привести

к повторению разрушительного процесса, происходившего в ходе ПК- и интернет-революций; направлению Digital Humanities, возможно, придется сыграть более активную роль не только в восприятии технологий, но и в их развитии [7].

Постановка проблемы

В рамках данной статьи нами предпринята попытка философского обоснования неотвратимости вхождения Digital Humanities не только как инструмента, но и как отдельного междисциплинарного направления в структуру гуманитарного знания.

Само по себе гуманитарное знание неоднородно. «Мы знаем, что границы гуманитарного знания, как внешние, так и внутренние, слишком размыты. Внутри себя каждая дисциплина содержит не только разделы, но и целый ряд школ и методов, некоторые из них ставят под сомнение правильность других, многие из них являются общими для нескольких дисциплин. По крайней мере, по внешним показателям некоторые гуманитарные дисциплины, например история, могут быть отнесены к социальным наукам. В целом же считается, что три или четыре дисциплины – философия, история, литературоведение и, возможно, антиковедение – составляют основу современного гуманитарного знания. И при этом мы знаем, что постоянно создаются новые или вспомогательные дисциплины (которым не хватает институциональной инфраструктуры полноценных дисциплин) в ответ на возникновение новых технологий или жанров (исследования телевидения, цифровые технологии в гуманитарных науках), или новых социальных, культурных, политических движений (гендерные исследования, постколониализм), или новых карьерных возможностей (музееведение), или новых функциональных связей с другими дисциплинами (деловая и профессиональная коммуникация), или просто нового спроса (писательское мастерство)» [1]. Причем воображаемые границы гуманитарной области время от времени «подвергаются атакам» со стороны областей точного знания. Например, Игорь Дмитриевич Навважай, доктор философских наук, профессор, заведующий кафедрой философии Саратовской государственной юридической академии, считает математику гуманитарной наукой и полагает, что она подобна лингвистике [3], так же как и Юрий Иванович Манин, российский математик, алгебраический геометр, член-корреспондент РАН, который придерживается мнения о том, что математика является отраслью филологии и лингвистики [2]. Еще в начале XX века ученые пытались применить математические методы в гуманитарных науках, в частности в лингвистике. Так был исследован роман А.С. Пушкина «Евгений Онегин» на предмет вероятности следования гласного или согласного звука за каждой буквой в произведении [4].

Любая область научного знания в своем развитии следует логике существования и взаимодействия структуры и ее элементов. Понятия элементов и структуры раз-

рабатываются с античных времен и трактуются в соответствии с представлениями о мироустройстве в целом. Пифагорейцы абсолютизировали структуру явлений и мира и объясняли состояние и степень устойчивости структуры количественными, числовыми соотношениями. Демокрит структурными особенностями наделяет атомы, многообразные сочетания которых есть тела/объекты, и считает причиной новых качественных состояний простое изменение структурной связи тех элементов, которые образуют явление.

Наиболее полное и детальное исследование сущности и соотношения элементов и структуры представлено в работе В.И. Свидерского «О диалектике элементов и структуры в объективном мире и в познании» [5]. В стремлении проследить закономерность в формировании и изменении структуры гуманитарной области знания воспользуемся терминологической трактовкой Свидерского, под элементами понимающего «любые явления, процессы, а также их свойства и отношения, находящиеся в какой-либо взаимной связи». Структура определяется им как «характер, закон связи элементов», их единство и способ взаимодействия, что вызывает возражение, а порой и раздражение некоторых философов (например, М.Н. Руткевича). Тем не менее само понятие структуры, трактующееся по-разному в ряде смежных областей знания, становится этаким категориальным инструментом в попытках объяснить суть и причину происходящих явлений, не желающих томиться в ожидании академического единодушия в вопросе дефиниции, как это происходит с Digital Humanities.

Методология

Не решаясь примкнуть ни к какому научному сообществу в данном вопросе, станем рассматривать структуру как процесс и в то же время как устойчивое состояние.

Любая структура, в том числе и структура гуманитарного знания, состоит из элементов, каждый из которых представляет собой некое единство устойчивости и изменчивости. И каждая структура конечна в плане возможности содержать («освоить») определенное количество элементов. Они связаны не только между собой, но и с другими явлениями/структурами и не могут быть однопорядковыми. Поэтому междисциплинарность – естественное состояние развития структуры гуманитарного знания. Основная структура может производить новые элементы, которые вызывают появление себе подобных и могут формироваться в иную структуру.

Таким образом, любая структура, простая или сложная, определяется ее элементами. Следовательно, она всецело зависит от них.

Незначительные изменения элементов не повлекут за собой разрушения структуры или образования новой, значит, она самостоятельна, но эта самостоятельность не абсолютна.

Характер изменений и развития элементов зависит от способа их связи и взаимодействия в рамках целого (структуры). Так, использование цифровых технологий всегда привязано к конкретной области знаний (история, лингвистика и др.) Отношения могут быть разными: соответствие, несоответствие, взаимообусловленность, противоречие и др. Структура может способствовать или не способствовать развитию элементов и работает при условии их соответствия или несоответствия по характеру, уровню или темпам изменения и развития. Прогрессирующие элементы приходят в противоречие со структурой. Условие разрешения противоречия – замена старой структуры новой. И это повторяется бесконечно. Следовательно, смена структуры в результате развития элементов закономерна. Требования к ней предъявляются не каким-либо ничтожным числом элементов, а всей их совокупностью, ибо они взаимосвязаны. Появляется новая структура, и она соответствует новым элементам. Таким образом, в развитии любого явления заложены тенденции отставания структуры от развития ее элементов и приведения структуры в соответствие с развивающимися элементами. Она не может оставаться однородной в меняющемся пространстве и течении времени. В нашем случае появление новой структуры вряд ли возможно, так как Digital Humanities по большей части носит прикладной характер, но качественное изменение самой структуры гуманитарного знания под воздействием стремительного развития одного из ее элементов все же видится неизбежным. В данной ситуации это очевидный способ «выживания» структуры.

Заключение

В настоящее время мы можем наблюдать некое переходное состояние структуры гуманитарного знания за счет нарастания элементов нового состояния, связанных с применением цифровых технологий в процессе исследования. Такое состояние можно назвать компромиссным, но это не может длиться бесконечно, потому как компромисс – состояние временное. Остается один выход: изменение структуры. В данном случае за счет включения в нее или же «признания» нового ее элемента – Digital Humanities.

Таким образом, никакая структура не может представлять собой статичное образование. Непременное условие ее существования – соответствие элементам, которые находятся в состоянии перманентного изменения.

Любые попытки насильственного сохранения структуры в неизменном виде обречены на провал. Так когда-то произошло с мертвыми ныне языками: они были задуманы вечными и неизменными, в то время как менялись люди, время, цивилизации.

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УДК 75.02

Как сделан «Черный квадрат»: методы оценки эстетической ценности живописи с точки зрения теории свободного распределения ресурсов

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Восприятие живописи во многом определяется социумом, его нормами, традициями, уровнем конформизма или нонконформизма. Идеальный пример влияния социума на восприятие живописи дает нам история импрессионизма. Но даже когда со временем традиции общества, в котором с муками рождался импрессионизм, ушли, и импрессионизм стал такой же классикой, как итальянская живопись эпохи Высокого Возрождения, возникает вопрос: почему мы считаем, что Клод Моне – гений, а какие-нибудь Альфред Сислей или Берта Моризо – лишь художники второго сорта? Что это – тоже традиция, сформировавшаяся в нашем обществе, или же есть объективная разница между картинами этих художников?

Существуют ли какие-то объективные показатели, позволяющие нам оценить **в цифрах** художественные достоинства картины? Можно ли объяснить с количественной точки зрения, почему мы считаем, например, «Черный квадрат» Казимира Малевича живописью, а не работой неумелого и наглого маляра – или шуткой мастера (кому как нравится)?

Обычно, когда пытаются ввести какие-то количественные показатели, используют те или иные математические методы. Действительно, существует несколько точек пересечения живописи и математики: теория перспективы, представление о золотом сечении в теории композиции [Раушенбах, 1980, 1986, 2001; Livio, 2002]. В настоящей работе рассмотрена возможность использования математических подходов для описания колористических характеристик картин.

После того как общество согласилось, что нефигуративная живопись тоже произведение искусства, можно не связывать качество картины с изображенным на ней сюжетом (если он там есть) и говорить, что любая картина в конечном счете представляет собой совокупность линий и множество цветовых и яркостных пятен и хорошая картина отличается от плохой тем, что эти пятна по-разному **организованы** в пространстве картины. Но как они организованы?

Художник, рисующий картину, в конечном счете имеет в своем распоряжении один ресурс – свою палитру, то есть набор цветов, которые он может нанести на пространство полотна. Если это так, то для описания **колористической организации** картины возможно использовать представление о распределении этого цветового или яркостного ресурса на плоскости. Следует понимать, что цветовые и яркостные пятна в определенном смысле конкурируют между собой в пространстве картины – если демиург-художник в точку полотна с координатами (X, Y) наносит красное пятно, то туда уже не нанесешь синее.

В нашей работе мы попытались использовать представление о распределении ресурса между конкурентами для описания организации цветовой и яркостной структуры отдельной картины. Для описания свободной конкуренции цветов за некоторый ограниченный (в данном случае пространственный) ресурс будем использовать классическую теорию свободного распределения ресурса между конкурентами любой природы. Эта теория ведет свое начало от работ Вильфредо Парето [Pareto, 2007], который применил ее для описания распределения доходов населения, и Дж. К. Ципфа [Zipf, 1949], использовавшего ее для описания распределения слов в некотором достаточно длинном тексте.

Начнем с определений. В цифровом представлении любая картина – это множество пикселей заданной малой площади. Каждый пиксел можно характеризовать определенным цветом и яркостью. Тогда цветовой колорит картины можно будет описать числом пикселей разных цветов в плоскости картины и вычислить функцию распределения этих пикселей по яркости и цвету. В простейшем случае цветовой спектр от красного цвета (примерно 760 нм) до фиолетового (около 400 нм) можно разделить на несколько классов и определить абсолютное и относительное число пикселей каждого класса в плоскости картины. Аналогичная процедура выполняется и для показателей яркости. Тогда картину можно описать функцией распределения цветов (от красного до фиолетового – рис. 1) и аналогичной функцией распределения по яркости.

Далее можно ранжировать все эти классы, начиная с класса с самым большим числом пикселей, которому присвоим ранг 1, и заканчивая классом с наименьшим числом пикселей – ему будет присвоен ранг 10. Следующий шаг – построение зависимости относительного значения пикселей в классе от ранга класса, это и есть ранговое распределение.

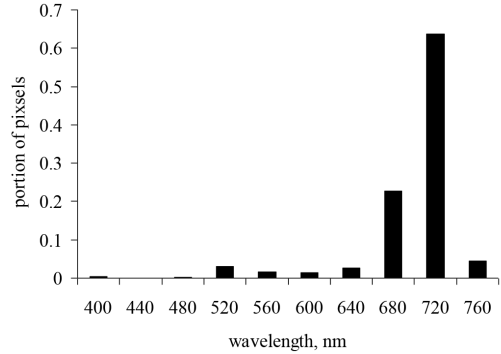


Рис. 1. Типичный вид распределения картины по цвету

Ранговое распределение относительного обилия пикселей разных цветов будем описывать с помощью уравнения Ципфа – Парето в двух формах: классической форме ZPEq (А) и в форме ZPMEq (Б), предложенной Бенуа Мандельбротом (Mandelbrot, 1965).

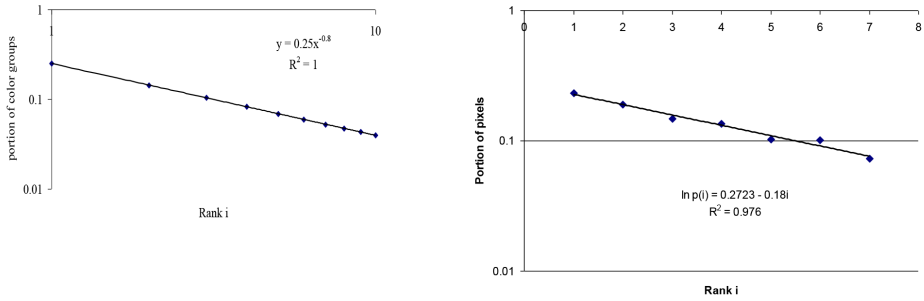
$$p(i) = iA^{-b} \text{ (ZPEq)} \qquad p(i) = A(i + B)^{-b} \text{ (ZPMEq)},$$

где i – ранг класса, p(i) – доля пикселей i-го класса, A, b и B – свободные параметры уравнений.

Для первого уравнения зависимость между относительным обилием p(i) пикселей отдельного цветового класса и рангом i класса будет представлять собой прямую в двойных логарифмических координатах (ln i – ln p(i)) (рис. 2А). Во втором случае эта зависимость будет прямой в координатах (ln p(i) – i) (рис. 2Б).

Таким образом, мы перевели цветовую и яркостную структуру картины в цифры и ввели три показателя для описания этой структуры – угол наклона, свободный член и коэффициент детерминации R^2, показывающий, насколько распределение цветов подчиняется уравнению свободной конкуренции. Чем ближе значение R^2 к 1, тем точнее изучаемое распределение описывается моделью свободной конкуренции.

Попробуем взять картины одного художника и посмотреть, как с точки зрения представлений о свободной конкуренции цветов организованы его картины. В качестве примера мы выбрали картины В. Ван Гога. Причин тому, что мы выбрали именно его, – две. Во-первых, авторы любят его картины, и, во-вторых, что самое главное, короткая творческая биография Ван Гога позволяет легко различить разные периоды его творчества и попробовать проследить за цифровой эволюцией



А Б

Рис. 2. Теоретическая форма рангового распределения долей пикселей разного цвета на картине (А – ZPEq; Б – уравнение ZPMEq)

Рис. 3. В. Ван Гог. «Пляж в Шевенингене в холодную погоду». 1883

стиля художника. На рис. 3 показана картина Ван Гога «Пляж в Шевенингене в холодную погоду», написанная в 1883 году.

Функция распределения цветов на этой картине приведена на рис. 4, а ранговое распределение цветов – на рис. 5.

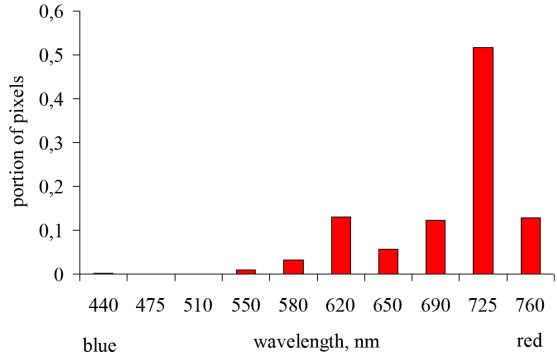


Рис. 4. Функция распределения цветов на картине «Пляж в Шевенингене в холодную погоду»

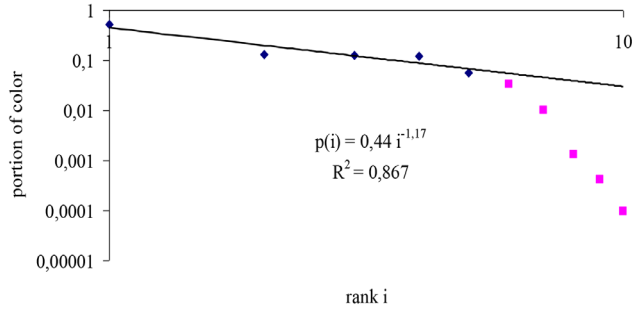


Рис. 5. Ранговое распределение цветов на картине «Пляж в Шевинингене в холодную погоду»

Как видно из рис. 5, художник использует в картине цвета только из пяти классов (пиксели остальных пяти классов цвета присутствуют на картине в виде своеобразного «шума»), и распределение пикселей этих цветов не слишком хорошо согласуется с ZPEq.

Прошло всего семь лет, и Ван Гог написал другую картину – «Поле пшеницы весной на рассвете» (рис. 6).

Ранговое распределение цветов на этой картине приведено на рис. 7.

Как видно, цветовая палитра на этой картине существенно шире, чем на ранней работе художника (пиксели всего трех классов встречаются на ней в виде «шума»),

Рис. 6. В. Ван Гог. «Поле пшеницы весной на рассвете». 1890

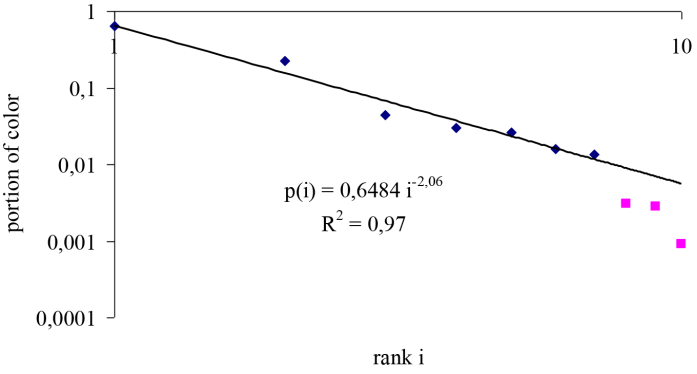


Рис. 7. Ранговое распределение цветов на картине В. Ван Гога «Поле пшеницы весной на рассвете»

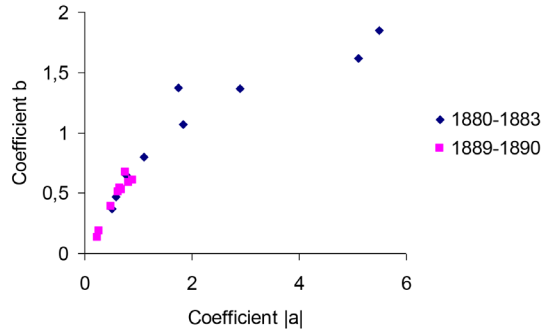
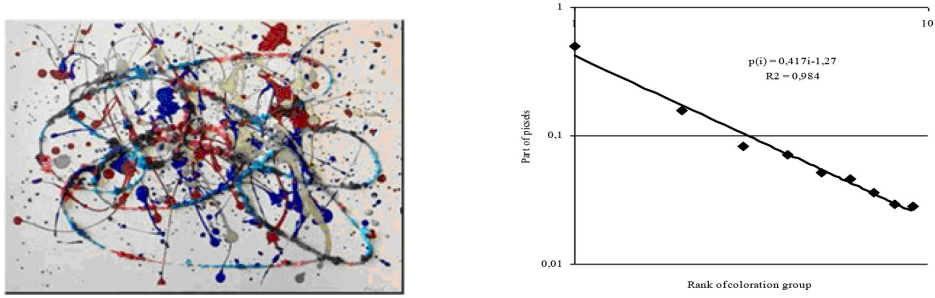


Рис. 8. Изменения стиля картин В. Ван Гога в цифровом представлении

а ранговое распределение использованных цветов практически точно (R^2 = 0.97) соответствует ZPEq.

График на рис. 8 в пространстве параметров уравнений рангового распределения для картин Ван Гога раннего (1880–1883 гг.) и позднего (1889–1890 гг.) периодов отражает стилистические изменения в творчестве художника.

Таким образом, можно говорить, что «поздний» Ван Гог пришел к организации цветового пространства своих картин в соответствии с принципами свободной конкуренции цветов на ней. Аналогичные расчеты можно выполнить и для характеристик яркости картин Ван Гога.



А Б

Рис. 9. Дж. Поллок ING 24_681 (А) и ранговое распределение этой картины по яркости (Б)

Рис. 10. Julia Timochovitch (11 лет). In Jerusalem

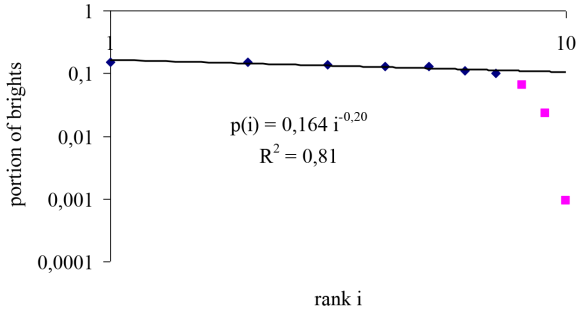


Рис. 11. Ранговое распределение пикселей картины In Jerusalem по яркости

Итак, «фигуративный» Ван Гог структурирован. Но структурирована ли абстрактная живопись? На рис. 9 показана картина Дж. Поллока ING 24_681 (А) и ранговое распределение этой картины по яркости (Б).

Можно утверждать (см. рис 9), что картины классиков абстракционизма организованы не в меньшей мере, чем картины представителей фигуральной живописи.

Но что можно сказать об уровне организации картин любителей или тех, кто только учится живописи? Для ответа на этот вопрос мы выбрали несколько картин детей,

Рис. 12. Odry Soroker. Landscape

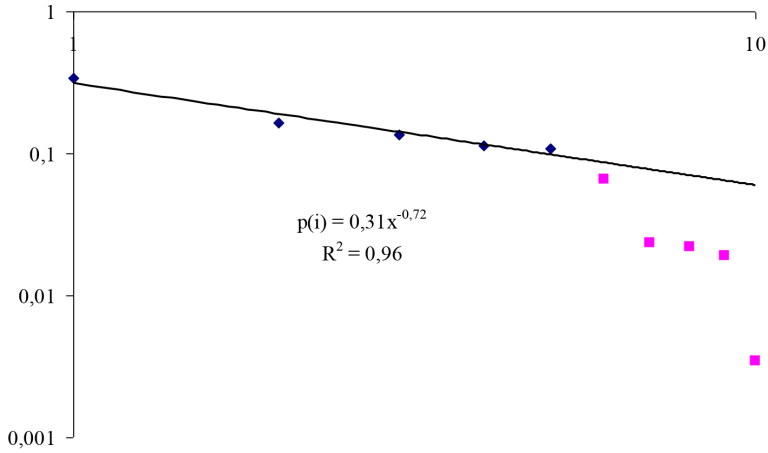


Рис. 13. Ранговое распределение пикселей по яркости в работе Odry Soroker Landscape

обучающихся в художественной студии в Кфар-Сабе – городе вблизи Тель-Авива (авторы благодарят руководителя студии Надю Гудман за предоставленные цифровые репродукции картин ее учеников). Это известная студия, ее ученики получили большое количество разных наград и призов на израильских и международных

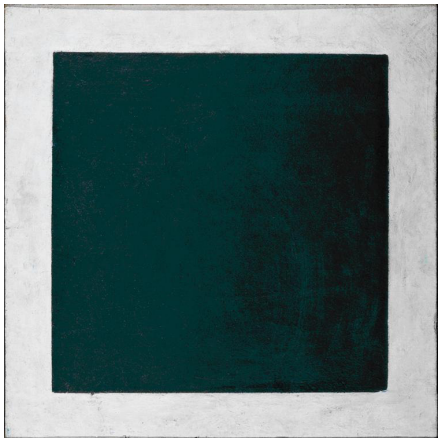


Рис. 14. К. Малевич. «Черный супрематический квадрат». 1915
(Вариант, хранящийся в Третьяковской галерее)

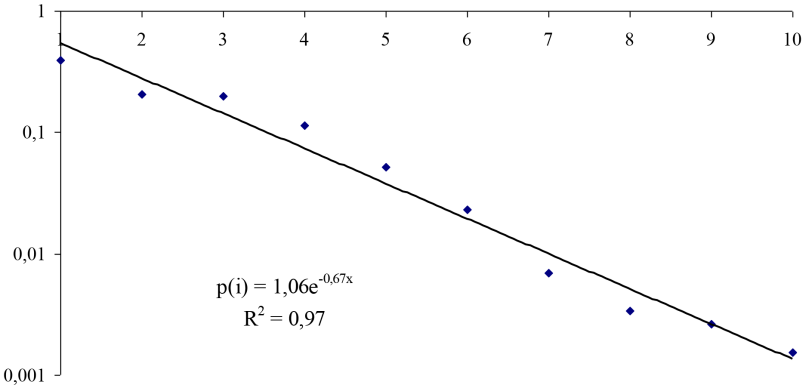


Рис. 15. Ранговое распределение пикселей по яркости в картине «Черный квадрат»

выставках детского рисунка, но всё же это дети, которые только учатся рисовать. Как же организованы цвета и яркость цветов в картинах детей?

На рис. 10. приведена работа Julia Timochovitch (11 лет) In Jerusalem, а на рис. 11 – ранговое распределение пикселей этой картины по яркости.

Как видно, согласие с ZPMEq не слишком хорошее, даже хуже, чем у «раннего» Ван Гога. Коэффициент b = 0.20 очень мал, что говорит об отсутствии яркостных акцен-

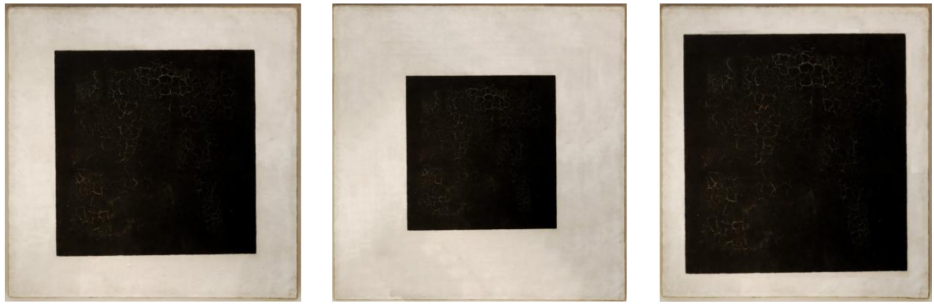


Рис. 16. «Черный квадрат» при разном соотношении базовых цветов – черного и белого. Слева – «Черный квадрат» Третьяковской галереи, в центре и справа – варианты с отличным соотношением базовых цветов

тов в работе: пиксели разных классов по яркости встречаются примерно одинаково часто.

Существенно ближе к теоретическому распределение по классам яркости в работе Odry Soroker (8 лет!) Landscape (рис. 12 и 13).

Однако число использованных девочкой классов яркости весьма мало (всего пять). Что делать – она еще учится.

И, наконец, перейдем к «Черному квадрату». Как вы видите на рис. 14 и 15, анализ показывает, что «Черный квадрат» организован ничуть не хуже картин Ван Гога, и с нашей цифровой точки зрения Малевич действительно художник, а не маляр.

Как известно, в науке существует два способа изучения ее объектов – наблюдение и эксперимент. Art science – наука, фокусирующаяся на наблюдениях художественных объектов. Другие науки, например современная физика, напротив, базируются на экспериментах. Однако предложенный в настоящей работе подход к описанию художественных объектов позволяет от наблюдений перейти к эксперименту. Эксперимент всегда – это ответ на какие-то заданные вопросы. И проводя эксперимент с таким структурно простым художественным объектом, как «Черный квадрат», можно попытаться задать вопросы, на которые трудно ответить, анализируя более сложные картины того же Ван Гога. Спросим: сохранилась бы организация «Черного квадрата», если бы между белыми полями и черным квадратом было бы иное соотношение площадей (рис. 16)?

Какой же из этих «черных квадратов» – действительно картина? Ответ можно видеть в табл. 1.

Таблица 1

Характеристики рангового распределения картины «Черный квадрат» при различных ее трансформациях

Соотношение площадей квадрата и белых полей вокруг него	Параметры рангового распределения			
	Тип уравнения	a	b	R^2
Оригинал:1.56	ZPMEq	0.05	-0.67	0.975
0.2	ZPMEq	-0.43	-0.78	0.950
0.5	ZPMEq	-0.09	-0.73	0.977
1	ZPMEq	0.03	-0.69	0.980
2	ZPMEq	0.04	-0.65	0.968
3	ZPMEq	0.001	-0.63	0.950

Как видно из табл. 1, соотношение между площадями черного квадрата и белых полей, при котором картина в целом описывается уравнением свободной конкуренции в некотором диапазоне значений, близких к тому значению, которое выбрал Малевич, выполняется. Для изображений с сильно уменьшенным (0.2) или увеличенным (3) соотношением площадей квадрата и белых полей вокруг него коэффициент детерминации R^2 существенно уменьшается – изображение уже не так хорошо удовлетворяет закону Ципфа – Парето – Мандельброта. Представляется, что вряд ли Малевич знал о законе Ципфа – Парето, но незнание этого закона не означает, что мастер (интуитивно) его не соблюдал. Все же – МАСТЕР.

Еще один вопрос: а что произойдет, если какую-нибудь картину разрезать на две части и рассмотреть отдельно цветовую и яркостную организацию каждой части? Сохранится ли после такого акта вандализма организация частей картины? И можно ли попытаться заработать, разрезая картины абстракционистов и продавая их по частям?

На рис. 17 показана картина В. Кандинского «Маленький сон в красном», а на рис. 18 – ранговое распределение по яркости для этой картины.

Проведем простой эксперимент: попробуем разрезать картину В. Кандинского на две половинки по вертикали (рис. 19) и вычислить ранговые распределения по яркости для этих половин (рис. 20).

Как видно из сопоставления рангового распределения на рис. 18 с ранговыми распределениями на рис. 20, распределение по яркости для левой и правой частей картины хуже согласуется с теоретической моделью рангового распределения по яркости для всей картины. Так что смысла разрезать картину нет – половинки не представишь как два шедевра.

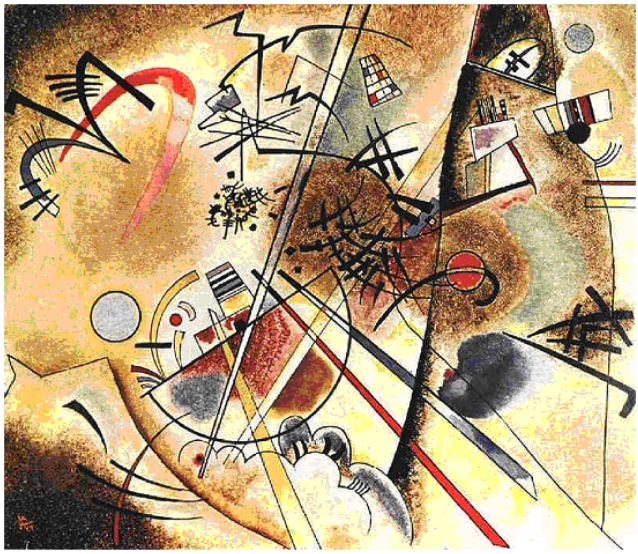


Рис. 17. В. Кандинский. «Маленький сон в красном». 1925

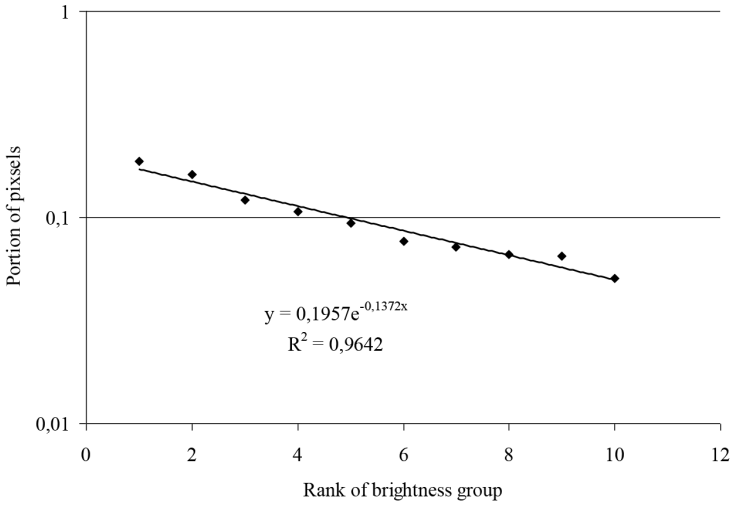
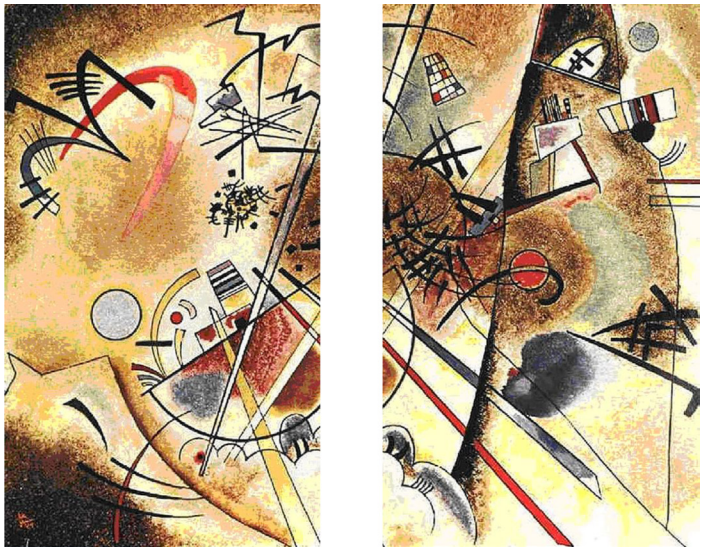


Рис. 18. Ранговое распределение пикселей по яркости картины «Маленький сон в красном»



L R

Рис. 19. Левая и правая части картины В. Кандинского «Маленький сон в красном»

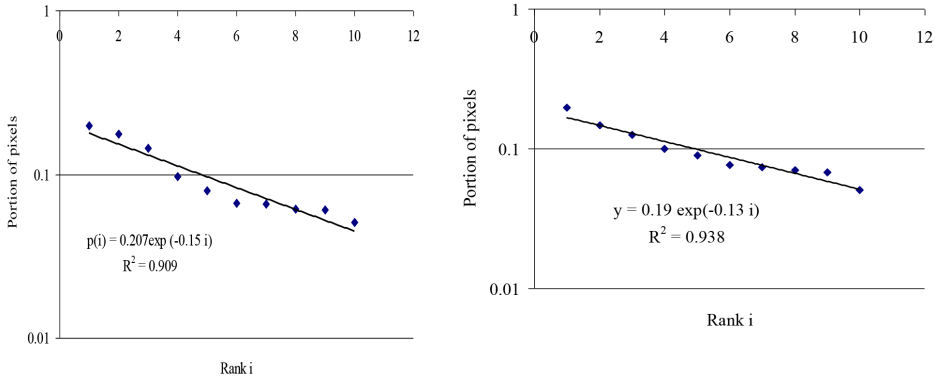


Рис. 20. Ранговые распределения по яркости картины В. Кандинского «Маленький сон в красном»; L – ранговое распределение по яркости для левой части картины; R – ранговое распределение по яркости для правой части картины

Конечно, проблема анализа организации живописного полотна не сводится к анализу интегрального распределения цветов. Безусловно, нужно принимать во внимание и распределение каждого цвета внутри пространства картины, и корреляцию различных цветов в этом пространстве, и форму линий (о чем мы не говорили совершенно).

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