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Mental model of a medieval scribe as a basic engine concept for an intelligent, bibliophilic book design system

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Abstract

This paper presents the current state of the research project which aims to build a mental model of an abstract medieval scribe. It will be the basis for the design of a novel intelligent engine for a book design system enabling to easily create books of exceptional artistic and bibliophilic value. A page of a book filled with illustrations, ornaments and text can be considered as an extension of the idea of a Turing Machine infinite tape. From this point of view, a mental model of a scribe can be considered as an extension of Alan Turing's concept of an abstract clerk-mathematician, processing a tape according to this tape's contents and the contents of his brain serving as a control module. Thus, authors want to expand the concept of the Turing Machine to design a model of an abstract medieval scribe and to use it as a basis for a future desktop publishing system. Joint knowledge of the authors on the practice of bibliophilic book edition and on the theory of artificial intelligence and expert systems provides a real chance that this project will be completed and implemented. This paper presents the basic theoretical foundations of the project.

Keywords: Turing Machine, clerk versus scribe, artificial intelligence, editing system, design system

1. Introduction

The daily work of contemporary book graphic designer and illustrator can be considered as a today's extrapolation of a medieval scribe's work whose job was calligraphing and illuminating medieval books in an abbey or monastery. The *horizon of examples* for such a scribe was restricted to perhaps fewer than 100 manuscripts available in his own or affiliated monasteries. Today, graphic designer and an illustrator uses 21st century editing tools and has access to the database of the whole Internet. Here *database of the Internet* is to be understood as a source of inspiration, examples and even ready graphical components. Despite the time-lapse of six centuries, the required result is the same: a beautiful bibliophilic book. The today's concept of e-books offers a great chance of demand explosion for books of an exceptional artistic form and bibliophilic character, but which are, at the same time, cheap and available for everybody in contrast to expensive medieval manuscripts. Thus, our intention is to build a theory and later to implement this theory in computer aided manufacturing system which will use artificial intelligence methods and a background Internet search to assist a human-editor or even replace him in creating a book on the artistic level of a medieval scribe as given in Figure 1.

Figure 1: Illuminated bible, 1407, Malmesbury Abbey, Wiltshire, England (Splendor, 2016)

Contemporary design applications like Adobe InDesign, Adobe Illustrator (Adobe, 2016) or QuarkXPress (2016),

and widely ubiquitous office-type applications like Microsoft Word (Microsoft, 2016) remain, for the most part, only lifeless tools in the hands of an artisan and amateur alike. Thus, they stay far behind what the today's technology of artificial intelligence and the database of the Internet is providing. Today, editors for web pages place greater emphasis on their appearance and artistic form, but it still cannot be compared to what a medieval scribe was able to do. Thus, new editing tools must be build, but to do this, a proper engine must first be built.

The structure of the paper is as follows: in the first part we will outline the process of bibliophilic book design in relation to contemporary methods and tools. Next, we will present the figure of the medieval scribe. Directly afterwards, we will move on to shortly describe the relation between the Turing's (1937) concept of a clerk and our vision of a scribe. The subsequent parts will present the idea of the model conceived by Kenneth Craik (1943) and a prototype of a complete model of scribe's mentality. The paper will be concluded with a summary containing a plan of further tasks and literature.

2. The nature of bibliophilic book design process

A book designer's work, although fulfilling and gratifying in its results, can also be, and often is, very tedious. While contemporary computer tools have dramatically improved some aspects of graphics design and typesetting, they have left other parts of the process neglected or even outright untouched. It is not the goal of this article to discuss these tools nor their effects in detail, but it aims to provide its reader with at least a hint of the overall situation.

The gain of digital technologies applied to the area of book design is largely a speedup of selected design -related activities. This speedup, in turn, is possible, thanks to the implementation of well-established physical tools and work practices as software components. These tools and practices are identifiable and intelligible by means of an observation of designer's external actions, so the nature of this observation is purely behaviouristic. Partly because of that, readily available automation in contemporary design tools is limited to the implementation of very specific and rigidly defined scenarios like, for example, page numbering. Such automation is sufficient and beneficial as long as the design requirements match the assumptions on which a piece of software was built, but as soon as these assumptions are exceeded, the designer is forced to fall back to manual methods, even though an automated solution seems to be within reach.

Automation, in the context of book design, can be perceived merely in the categories of sheer speed and convenience, but also – and even more importantly so – in terms of a delegation of the designer's creative competencies to an automated system. This delegation is exactly what the designer does when, for example, he or she lets computer software place numbers on pages without his or her direct supervision. The more parts of design process are ceded to software, the less strain is put on a human designer, who can then focus on *designing* itself rather than on *tedious chores*. At the extreme, a properly crafted system could even be able to act as a kind of virtual intelligent designer in lieu of a human specialist who, in turn, would assume a different role as a source of general suggestions and requirements if he were to act at all.

Just as we expect a human designer to produce a beautiful book, so we should expect, and even require, the same from an intelligent design system. Our aim is not a system able to design (in an assisted or fully autonomic way) simply *some* book (indeed, such systems are already there) but a system capable of yielding truly beautiful results. One way to tackle this challenge would be to follow the previously mentioned behavioural analysis. Despite the fact that ever more subscenarios of the design process, suiting ever different cases, could always be observed and then implemented, it would lead us only as far as to a kind of an elaborate template-based, grid-driven system. Although products of such a system are not inherently unimpressive or aesthetically unpleasing (The Grid, 2016), they are most certainly quite heavily constrained by something we could call a form-oriented paradigm, that is a design methodology treating composition as a set of rigidly defined fields filled-in with separate content fragments. Making a comprehensible framework, it also promotes a sort of aesthetic inflexibility – designs looking basically *the same* regardless of their content. This unidirectional influence of composition on the content can only be broken by a human intervention, for example, by designing a new template.

Another, very recent and already somewhat controversial, example of an attempt to turn a computer into an artist is The Next Rembrandt (2016) project. Although at the time of writing only some general information was available, still, thanks to what is known, it is possible to make some assumptions about the project. In contrast to the previously mentioned The Grid (2016), The Next Rembrandt seems to be, to a degree, freed from the form-based regularity, which is in fact a necessity for a system oriented on the art of painting. For our purposes, the most interesting aspects of the project (apart from the components responsible for the process of painting itself) were how Rembrandt's artistic style was extracted from his paintings and how it was rep-

resented. Unfortunately, as former undertakings, The Next Rembrandt project appears to be heavily behaviouristic, focusing on an elaborate statistic of paintings and their features, while disregarding their deeper contents and meaning represented in facial expressions, eyes or poses. This is good enough to produce a very impressive feature-based portrait (which is deemed to be the statistically most probable subject of the next Rembrandt's painting, if he was still alive), but not good enough to fulfil a commission of a person who would like to be painted by Rembrandt or to have *a biblical scene* newly made by the Dutch master. The problem is the system that does not know how to pose a subject, what does a biblical scene mean or, in fact, how to use a real brush and paints, let alone how to mix them for the desired effect. Other potential problems and unknowns are the methodology of digitalization (the colour space of the input device is prone to lose portions of the original colour information perfectly perceivable by the human eye), the colour model and the working space in which the data was handled and, finally, the exact print technology. However, while being potentially very important, these are, as of yet, unknown details.

Although the image presented on the project's official website bears noticeable marks of being digital art (like tell-tale signs of non-painterly blurs in the shadow under the nose, on the right cheek or in the transition between the left side of the beard and the collar), it still should be considered a very successful example of an important and applaudable effort (Figure 2). Let this remark serve as a well-deserved counterweight to the otherwise critical assessment of The Next Rembrandt project we present here.

Figure 2: A portrait from The Next Rembrandt (2016) website

Once again, it appears that to be successful in mimicking an artist, we need to go much deeper than statistics and a purely behaviouristic analysis. It is not enough to know how something was made technically; we also have to know, understand and be able to recreate the whole inner, mental story behind it.

Since the human factor seems to be essential, we should ask the question: *How does one design a beautiful book?* and try to answer it in a much broader sense than just behavioural. It takes more to design than to fill-in predefined placeholders it takes to understand the content and the entirety of the design process happening both in a human mind and in the environment which contains, surrounds and influences this mind.

Here we are due a few words about what does the adjective *beautiful* mean in our context, why do we use it and what criterions are we to apply to recognize a *beautiful book*. While it may never be possible to express in scientific terms what is *beautiful*, the very existence of the word proves that there is such thing as *beauty* and, what follows, some features determining its elements in a work of art – a book, for example. Recognizing beauty is somewhat similar to recognizing civilisation. About the latter Kenneth Clark (1977), a renowned art historian, aesthetician and art connoisseur, said: *What is civilisation? I don't know. I can't describe it in abstract terms. Yet. But I think I can recognize it when I see it and I'm looking at it now.* These words were spoken on the banks of Seine with a sight of a medieval cathedral in the background. While we may have trouble with defining *beauty* in less than a few tomes of a philosophical treatise, it's hard to imagine anybody would judge Michelangelo's David, for example, as anything less than beautiful. The same can largely be said of many medieval manuscripts. Subjectivity of the judgement itself doesn't make it altogether useless. What is more, in relation to the established examples of art widely deemed *beautiful* it gives us a kind of comparatory criterion, according to which products of our own system could be evaluated.

By stating explicitly that we expect *beautiful* results from our automatic and autonomic book design system we also hope to gain a certain psychological effect. The name itself doesn't allow the researcher to forget about the scale and goal of his/her enterprise. It is noteworthy that J.C.R. Licklider (1963), one of the ARPA (Advanced Research Projects Agency) directors and researchers, called his concept resulting in the emergence of ARPANet (which could be seen as a proto-Internet) *Intergalactic Computer Network*. Were we to settle on anything less than *beautiful*, we would fall into the same trap of ambiguity we just described without gaining anything in return. On the extreme we could lower our ambitions and skip any adjective altogether but that would simply mean construction of an automatic and autonomic system producing books. That in turn would mean re-inventing another TeX, DSSSL (Document Style Semantics and Specification Language), CSS (Cascading Style Sheets) and the like.

To explain and understand how a beautiful book is made (Tymms and Wyatt, 1860; Putnam, 1896; Johnston, 1906; Frutiger, 1989; Tillotson, 2016), we have to take a look at what is inside the designer's mind and build a model of it. This insight will give us a far better grasp of what is essential to the design process as a whole and

will be a crucial step on the way to the construction of an intelligent book design system. First, however, we need to select a fitting designer to investigate. We could try to take a look into the mind of a contemporary designer but with the multitude of inspirations, styles, stimuli and tools available and present nowadays we are at a serious risk of being overwhelmed by details before we would even start to notice any desirable patterns in the workings of his/her mind. We need an example of a designer relatively isolated to make his/her inspiration sources limited and emotions ordered and therefore more feasible for analysis. At the same time our designer should be able to produce works reaching far beyond simplistic banality – works which could be considered beautiful. Incidentally we find all of these characteristics in a person of a medieval scribe.

3. The scribe

Before we proceed to construct a prototype of a mental model for a medieval scribe, it is crucial to get to know who he was, what he did and how he did it in all the necessary historical and cultural contexts. Only then we will be able to decide what the term *medieval scribe* will mean to us.

Firstly, we should clearly state what is to be considered medieval in temporal, geographical and cultural meanings. Although the equivalently used term *Middle Ages* suggests only the first kind of interpretation, it is worth noting that in historiography the *medieval period* is inseparably connected with Europe, understood mostly as a sphere of a specific culture. This notion is also reaffirmed by the choice of historical events marking the beginning and the end of the era. In the contemporary view of the world, we can say that the sphere of the European culture expanded from the territories of both the Western and Eastern Roman Empires, North Africa and the westernmost parts of the Middle East to what is now known as the European continent (including Great Britain, Ireland and Iceland along with Scandinavia). As a consequence of slightly different Roman and Greek heritages, European culture grew in two stems, an Eastern and a Western one – each prevalent in basically its own respective *half* of Europe. For our purposes, we will consider the Western one because of its rich scribal traditions, art, forms of expression and artefacts of which are still relatively easily accessible today.

Having crudely established the cultural frame of our interest, we should now do the same time-wise. The medieval period is considered to span about 1 000 years – from the 5th to the 15th or even early 16th century. The dates of the boundary events marking the period are not universally agreed upon, as are the events themselves; however, they all point at the given centuries. This fact combined with the knowledge that the process of the cultural change from antiquity to medieval and from medieval to Renaissance was evolutionary and not revolutionary in its nature allows us to settle on this very loose time frame, even though it may be rough for many other uses. Before we further continue our description, a word should be said about the purpose of the trade of scribe. It can be asserted that the main impulse driving its development was the spreading of Christianity. Missionary work called for a reference and support in the form of liturgical, biblical and other religious texts. At that time, the only practical way of providing them was copying by hand. Because of the profile of the copied works and the demise of secular literacy, the bulk of the medieval pieces of scribal work are products of monastic societies. Most notable of these societies are the Benedictines (Oliver, 2016) (with their famous monastery of Monte Cassino), Cistercians (Oliver, 2015) and Carthusians (Girard, 2016).

Although the Christian religion was the main focus of medieval research and publication, it does not mean that the earlier, pre-Christian works were altogether discarded; on the contrary, many of the great works of pagan antiquity were preserved and copied in medieval monasteries, thus saving them for the generations to come. If it had not been for that, they would have been almost certainly lost forever in the tumultuous years of the medieval period.

Apart from the preservation and transmission of the already existing texts, mostly religious in their nature, monastic life was also a rich source of original works dealing with almost all aspects of the contemporary world. Their reach beyond the boundaries of a simple recapitulation allowed for the further development of philosophical ideas, leading to the subsequent onset of the Renaissance. Generally, monasteries remained the main centres of scribal activities, and of culture itself, for almost all of the Middle Ages, giving way to secular scriptoria (and later to print shops) only at the end of the period.

So far we can assume that our scribe is a western European monk, living between the 5th and the 15th century. Let us also take the liberty of arbitrarily setting his interests and competencies to the copying work, illumination and illustration, especially since it is often very hard to distinguish between the two latter forms. It seems to be a quite practical and justifiable choice in the light of this paper's goals.

Moving forward from the broad view presented so far, we shall take a look at the environment our monk scribe lived in and, more specifically, at his craft and art.

The living environment can be considered as a direct source of inspiration, a source of the ideas which transpire into the results of a scribe's work. This inspiration can be immediate (simple mimicking of solutions seen in other works) or more elaborate, based on personal experiences, both physical and mental ones. All kinds of inspiration can be used in the process of producing a copy of another book. Here we have to note that the word *copied* refers, for the most part, to the text of the book. It was really the text that was copied; other aspects of the book, like its form, page composition, illustration or illumination were frequently questions at the scribe's own discretion. His *choice*, in turn, is another point of interaction between the scribe's own creativity and the environment, because the scribe's *choices* can be influenced by, for example, his superiors or collaborators (who are also a part of the environment). This type of interaction is an assumption; however, it appears quite reasonable to assume that some kind of *control* over the work of scribes had to be exerted. Otherwise, the likelihood of introducing some serious doctrinal or technical errors into the copied works would have been so high that such occurrences would be easy to spot in the surviving examples of medieval books and such cases would be well known. If such a kind of control had been in place, then it is almost natural that its role would not have ended only on a meritorious verification, but it would also have spread to the area of the work's aesthetics.

Before we move on, we have to clarify a couple of potentially problematic subjects. The first one is a matter of scribe's living environment, that is: chiefly his monastery. Undeniably all of the religious orders mentioned before – Benedictines, Cistercians and Carthusians – sought some kind of isolation from the outside world. This isolation however, immediately noticeable in its material manifestation of thick, closed walls, should be primarily seen as an attempt to isolate the monastic family from the world's dangers, turmoil and *spiritual toxicity*, not from the nature or populace. The former becomes almost self-evident in places like, for example, Grande Chartreuse or Monte Cassino. This kind of isolation is in fact very opportune for our needs because it allows us to narrow down potential sources of scribal inspiration and shorten the probable reasoning path from an idea to its expression on the pages of a book.

Another interesting aspect of a medieval scribe archetype we have to take into account here is his will and choices he makes in relation to his vows of obedience. It is not inconceivable to think that obedience of a monk to his superior meant a total submission of the former to the latter in the every aspect of life. Religious sources however do not treat obedience as total, that is, precluding any activity unless it was sanctioned by the superior. Monastic obedience did not prevent free will, human artistic creativity or conscience to work. Perhaps the most elegant and clear explanation on the matter of obedience is given by St. Thomas Aquinas in his *Summa Theologica* (1920, Q. 104, Art. 5). He writes that the vows of obedience are not binding when a superior requests of a subordinate an action which is contrary to God's Commandments and Gospel. In the same text it is expressed that the obedience should be complete but in the things that are due to the specific authority. Obedience was treated as a voluntary and limited submission of one's own will grounded deeply in Christian theology and directed towards one's personal path to salvation guided by a more spiritually experienced person. In general, obedience is to be understood as a tool of spiritual guidance not an absolute and unquestionable control. While superior had an objective authority over a monk-scribe it doesn't mean that it placed the latter in the role of a mere desultory automaton micro-managed by the former.

In this quick sketch of the scribe's environment and condition, there is one last element to describe: the technological process of producing a manuscript. Historical sources tell us that it consisted of many stages: from preparing parchment, coloured inks and golden leafs, through using all of these in the actual act of writing, painting and illumination of a book, up to binding the pages and introducing the cover. Each of these stages required a very specific set of knowledge, experience and predispositions, so most often they were performed by different persons purposely delegated to one of these tasks. There were, however, cases when a single man was able to (or was compelled to) do multiple of these activities in person. Even if the scribe himself was not involved in all of the preparations of a book and materials, still he must have been conscious of his medium and tools – their specificity, abilities and shortcomings – to properly plan his actions and to execute them successfully.

When mentioning the medium and tools, we should once again take a look at the scribe's environment; this time, as an instructive source of information about the new or perfected methods of work. After all, our scribe had to learn and keep improving his trade. He must have been able to discover some of its secrets by himself, but he had to learn other skills, most probably in person, from more experienced scribes. There were almost no *manuals* on the craft and art of calligraphy, as well as book decoration, illustration and illumination. *Almost* does not mean *none*; there is one noteworthy example of this type work, but it was written only in the late Middle Ages and its existence even more vividly supports the claim about the rarity of *scribal handbooks*. Besides, not all of the knowledge could be efficiently passed using the written media; some had to be presented firsthand and then practiced in controlled conditions to achieve the desired level of proficiency.

Researchers studying old manuscripts noticed that there are certain similarities (be it similar motifs, aesthetic forms or technologies) between books authored in different centres of scribal culture. This palaeographical clues allow us to conclude that there existed not only an exchange of the *raw* material in the form of textual content to be copied but also an exchange of methods of work. Findings based on an inspection of unfinished manuscripts and illuminations are even more valuable for our purposes. While being quite common, they present a unique opportunity to infer the order in which the work progressed and how it had been planned beforehand.

So far, we have constructed, in a very brief and concise manner, an image of a medieval scribe and the world he lived in. Unfortunately, for the sake of the above mentioned brevity, many details had to be omitted. Such omission would be an unforgivable act, should this paper aspire to the status of an achievement in the fields of palaeography or historiography, but in our case some, even serious, simplifications can be made. After all, we aim for the comprehensibility of a prototypical model of a medieval scribe's mind and mentality we are about to present in this article, and not for full historical accuracy.

Having sketched our subject person in the specificity of his times, we should now think about the way we can turn the knowledge we have gained up to this point into a model of a scribe's mind. To that effect, we can take a look at the story behind the famous Turing Machine as a source of inspiration. Therefore we shall now follow Turing's clerk in his relation to the machine developed upon him, parallelly use this relation to find out what are the characteristics of a successful automaton and identify similar characteristics in our scribe. Since we want to use scribe's model as a basis for the *virtual scribe*, this knowledge will be very important for us, even though the purpose and abilities of Turing Machine are very different.

4. Clerk vs. scribe

If we will compare Alan Turing's clerk-mathematician (Turing, 1937) and a medieval scribe, we will find astonishing similarity. The clerk-mathematician by definition had to be an outstanding mind, but Figure 3 shows how his office environment was trying to make him automate. Even today, some mathematicians underline the discipline of mathematical thinking. Thus, for Alan Turing it was natural to replace a mathematician with an automaton in a formal way. The same applied to a medieval scribe (see Figure 4): his outstanding mental abilities did not release him from the monastery discipline and work discipline when copying and illuminating books. However, the nature of this discipline is quite different for each of them. The authority the discipline holds over the clerk is absolute. He cannot escape or contest it. He also cannot do anything outside of the regime he is subjected to. Consequently, his work is devoid of his own invention, which can be as much a blessing as it can be a liability, especially in the context of book design, where artistic invention is always desired, even if it is in the smallest of matters.

Whereas the clerk's discipline is, by design, an inseparable part of his *mentality*, it plays more of an auxiliary role for the scribe. It surely is there and cannot be simply ignored, but it does not mean that its lines cannot be crossed or broken. It is, after all, something the scribe had to accept on his own and by his own free will. The grounds on which he based his acceptance, whether they were physical or metaphysical, remain a different matter. Anyway, the structure and authority of the discipline (disciplines) the scribe accepted still left him much room to think and act as he pleased, which was enough to keep him *creative* while guarding him from being heretic. So, both the clerk and the scribe are subject to some kind of a discipline but in a different sense and to an unequal degree.

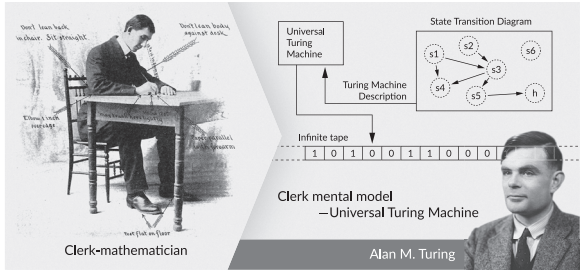

Figure 3: From clerk-mathematician to Turing Machine; authors' composition based on the photograph from The Business Educator, January 1909 (Leslie, 1909)

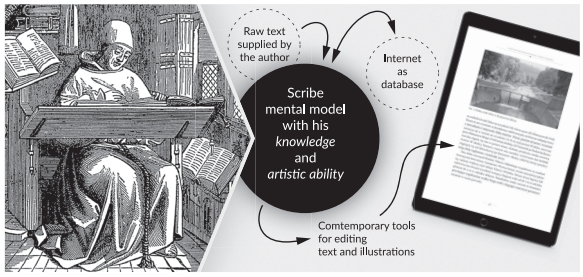

Figure 4: From medieval scribe to engine for future intelligent book design system; authors' composition containing illustration of a scribe from Lacroix (1875, p. 432)

Another point of tangency when it comes to the clerk and the scribe are their minds, or rather states of their minds. The clerk's *state of mind* is treated simply as a *state* of the automaton he is being turned into, an indivisible

and opaque entity, denoted by a discretionary symbol. The function of this *state of mind* could be summed up as a kind of *scratch-memory* for the operations carried over the paper tape and for that purpose it is quite sufficient. However, it ceases to be so for our scribe, because his mind is expected to hold an internal *image* of the world around him and, specifically, of the piece of art he is working on. It is next to impossible to try to denote such a very detail-rich scene of imagination with a single symbol (the required number of such discrete symbols would have a tendency to quickly explode to infinity without bringing anything useful into the picture). Besides, we need to be able to manipulate this scene and its components, so we must steer clear of any temptation to assume its immutability, which would be implied if a symbol was used to denote it. For that intent, we have to devise our own way to represent the scribe's mind and its inner workings. Again we are confronted with a similarity between clerk and scribe, which also proves to be a crossroad leading us on a rather different path from the one Turing took in his work.

From the comparison of the clerk's and the scribe's minds, let us move to another issue: the objects and means of both the clerk's and the scribe's work. While the clerk's only imprint on the world can be symbols from a well-defined, finite set, the scribe's arsenal of expression is by comparison virtually infinite. What is more, the clerk does not even have to *understand* the symbols he is using. It is enough for him to be able to recognize, delete and write them. While this makes the clerk-machine quite straightforward to make at the same time it raises a barrier between the concepts used by this machine and the concepts which are natural for its controller, i.e. a human being. This is a barrier which as yet is somewhat lowered, but has not been not removed completely.

Symbols used by the clerk are by their nature and due to the clerk's abilities indivisible. It is very different with the scribe's objects of work, which are pages of parchment filled with letters and embellished with ornaments and pictures. In a very general and low-level sense, we could say that as the clerk writes symbols, the scribe puts areas of colorants, but while for the clerk these symbols are devoid of any meaning, for the scribe it is the contrary: it is the meaning that dictates the specific shape and composition of all the areas marked with ink or paint. Meaning, however, does not exist on its own and by its own. It requires a mind. Thus, everything the scribe does to the page is to some degree a reflection of the concepts in his mind. What is more, these concepts (or, as we will identify them later, *mental models*) are not monolithic. They can be (and indeed, often are) deconstructed and reconstructed again between themselves for some novel effects. Old manuscripts are abundant with proofs for that. To be convinced of that, it is enough to look at fantastic beasts guarding the wisdom contained within the pages. While none of them existed or exists in reality, we can often recognize elements of dogs, lions, birds of prey, fishes and the like in them, all mixed-up in a splendid creature: an amalgam of concepts. This is not to say that everything the scribe does is chaotic and unstructured. Quite the opposite, each of the cross-concept combinations mentioned is seamless and well ordered, which means that even such constructs are guided by something, perhaps other more general or abstract concepts.

Before we move on to consider the clerk's and the scribe's respective means of work, we should take note of two important consequences of the freshly introduced *concepts of mind*. First, the sheer fact that they can be decomposed and re-composed again allows us to conclude that they must consist of *lower-level* concepts. Additionally it is possible that each of these *lower-level* concepts could be shared by two or more other concepts, thus, in great simplification, providing a kind of information *compression* method for the mind (Schmidhuber, 2009). The second consequence is that we cannot in all honesty describe the work of the scribe as *creative*. If the verb *to create* is to be understood as an act of bringing something previously non-existent into being, in part or as a whole, i.e. making something to exist out of nothing, then we cannot use it in relation to the scribe's work. Such was the meaning of *to create* in the Middle Ages. The only thing we can say about the scribe's efforts is that they are a kind of mimicking of proper creative ability.

Now, we have to consider the means by which both the clerk and the scribe do their work. For the former, it is enough to be able to read, write or erase a symbol as a whole and to move between cells containing the said symbols. All that is neatly represented in the Turing Machine by movements and abilities of a header and the paper tape. This straightforwardness is again a bliss for any potential implementer interested in purely computational advantages of the clerk analogy but a serious nuisance for anyone trying to directly utilize this model to simulate work of the scribe. The scribe cannot let himself compartmentalize elements of his work in quite the same manner the clerk can. Firstly, these elements relate to meaningful internal concepts which on the page of a book are separated not so much spatially (as the clerk's symbols) but semantically. Secondly, concepts can be connected between themselves both internally in the scribe's imagination and externally as their graphical representations. Simple, undividable symbols are not up to that task. Thirdly, the scribe cannot focus only on particular elements of his design; he has to be able to consider it once as a whole, the other time as a sum of its parts and finally as separate elements requiring special attention. To do that, he needs much more than *reading/writing head*: he needs quills, brushes, special blades, inks and paints with which he can operate

on virtually unrestricted area of a page (any restriction is of his choosing and serves the purpose of a comprehensible layout). Only with these tools the scribe is able to visually encapsulate a scene of his imagination and do his work. A silent consequence of stating this is that apart from physical tools the scribe also has to have their *models* in his mind. To sum up, comparing the clerk's and the scribe's tools of expression (understood as tools by which they can influence the outside world) is like comparing a set of rubber stamps to a whole spectrum of artistic means.

As we discuss the differences and similarities between the clerk and the scribe, one more thing needs our attention. It is an answer to the question of what propels actions of our protagonists. In the case of the clerk, we can say that the motor of everything he does is a table of instructions together with a kind of arbitrary *clock* forcing ceaseless execution of the said table. It is completely sufficient for his type of activity. Unfortunately for us, this also means that the clerk does not have any autonomy. Autonomy (at least partial) in turn is a condition *sine qua non* for any system striving to provide as mature and sophisticated results as the art of a medieval scribe. Without any autonomy our system would simply execute a program, which inevitably leads us to the conclusion that such a system is not intelligent and represents at most a behavioural stimulus-response model. Therefore, we cannot simply follow the clerk's case and we have to come up with another solution respecting the scribe's autonomy but at the same time not allowing for stagnation in the face of an abundance of different paths of action to take. In other words, we need something that will allow our scribe to more or less autonomously set his goal, and a facility allowing him to reach it. A quite natural and intuitive candidate for the role of the latter seems to be a *narrative*. After all, *internal narrative* accompanies every thought process we can recall and it appears to run continuously throughout our conscious hours and even beyond them. Now, if we give specific parts of the scribe's psyche an ability to take over the narrative, we should have a recipe for a psychological motor for the scribe's thoughts and actions (which can be pictured as an external projection of thoughts through the means of the body).

To sum up our comparison, we will compare the most important characteristics of the clerk and the scribe in Table 1.

Table 1: Comparison of clerk and scribe

Aspect	**Clerk**	**Scribe**
State of mind	Single, indivisible, opaque state	A living stage populated with models, governed by the narrator
Subject of actions	Symbols on a tape – opaque and immutable, like the state of mind	Pages of the book (the book itself)
Motor of actions	A table of instructions, external to mind, constructed from predefined sets of symbols, states and elementary actions over a tape	A narrator, internal to mind
Basis of personality	Disregarded	Built by experience
Ability to learn/change	Indirect – a clerk may potentially create another, better clerk if the results of his work are to be interpreted this way	May enhance and change his mental models, both consciously and unconsciously

5. What is a mental model?

In the previous section we used the terms *model* or *concept* to denote an internal representation (an image) of reality or its parts in the scribe's mind. Now, we shall elaborate on this matter and introduce another term, *mental model*, which from now on will replace the ones used before.

A mental model is a term originating from the fields of psychology and philosophy (Thagard, 2010; Johnson-Laird, 2004; Kurzweil, 2012). In short, it can be explained as a description of the way one thinks about the reality by means of *small-scale models* (Craik, 1943) representing this reality. The term is popular especially in psychology, sociology and, cognitive sciences, but its use is not restricted only to them. Mental models are also used in marketing and – more recently – in web design industry, where they serve as a way to understand clients' needs and wishes. Another area where mental models are extensively utilized is the field of human-computer interaction studies. In all of these disciplines, however, mental models are made to be used directly by a human, while we intend to use our

model as a basis for an automatic and autonomic system. In other words: we want to turn our model, as directly as possible, into a machine. We don't seek to create another design tool with more refined user interface but an *artificial designer* itself.

It is widely believed that the term *mental model* was first coined by a Scottish philosopher and psychologist Kenneth Craik in his work "The Nature of Explanation" (Craik, 1943). Although some earlier works bare traces of similar concepts, they fall short in comparison to Craik's work in completeness and clearness of the proposition. Craik says: *If the organism carries "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is best of them, react to future situations before they arise, utilize the knowledge of the past events in dealing with the present and the future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it.*

This sentence, regardless of its undisputed, and often explicitly noted, vagueness, provides a powerful idea. Despite the strongly emphasized predictive and improving role of a *small-scale model*, a clear image of a mind as a *sandbox for testing different alternative lines of action* emerges from it. Its vagueness can also be a blessing in disguise, because, thanks to it, there is much potential for exploring different architectures of the *model*, while the idea itself remains a clean launchpad for such exploration, without any cruft which would have to be stripped from it beforehand.

In the light of the earlier comparison between the Turing's clerk and the medieval scribe, it does not take a big leap in reasoning to realize that Craik's idea is a good starting point for a journey into a book designer's mind. It should not be too hard, especially for those who, at least once, had to design a book, or any other thing, to perform an auto-examination of their mind at the time of *designing*. Any *design* begins its life not so much on a drawing board or a piece of paper, but in one's imagination as an entity being a *small-scale model* of a portion of reality, or, more strictly speaking, potential reality. So is the case with a book and it is only natural to take a mental model concept and expand upon it.

6. A mental model prototype

Before we attempt to describe our prototype of the scribe's mental model, we have to distinguish between two different meanings we use the word *model* in. The first meaning relates to the whole of the scribe's mentality which we are attempting to postulate here. The second one is reserved for any small-scale *imprint* of reality in the scribe's mind. As such a *model* in the second meaning is only one of a whole set of elements within the first *model*. This information, along with the context the word *model* appears in, should be enough to disambiguate the word.

Now it is time for us to introduce a diagram (Figure 5) illustrating our proposition of the scribe's mental model.

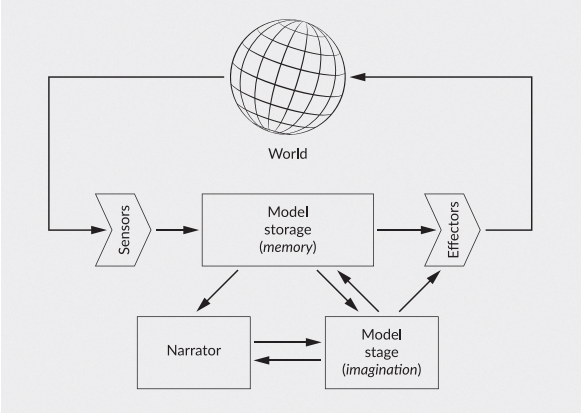

Figure 5: Scribe's mental model

Even though it may seem a bit crude and overly simplistic for such a formidable task as making a beautiful manuscript, it has a potential to account for a quite surprising variety of real life scenarios including, above all, scribal artisanship.

One thing to note is that although the world is presented here as a separate entity, the scribe's mentality, along with the body containing it, is actually also a part of this world, which is of consequence for self-consciousness as the world can affect us directly not only mentally but also corporally.

First, let us take a general look at the parts of the diagram. We may start with the *sensors*. Unsurprisingly, they represent senses, both in the classical, like sight or smell, and a more contemporary meaning, like balance. By being immersed in the world, they detect specific physical phenomena and translate their observations into other phenomena, proper and *understandable* for the rest of the system. It is roughly equivalent to a head reading signs from a tape in the Turing Machine.

Moving on, we now step into the next block, designated as *model storage or memory*. We could also call it *modelling fabric* because it is used to form and retain models. Its responsibility is twofold. As the name itself suggests, it serves as a storage place for all the mind's models (small-scale models or concepts) but its task is also to detect patterns (regularities) in sensory information and in whatever happens in imagination (this

ability is marked by arrows pointing towards the block). Any pattern previously experienced is noted, possibly by *activation* of the model and by informing the narrator about its detection, and refined. Any new regularity, on the other hand, will be used in an attempt to formulate a new model. From the *memory storage* we skip along one of the arrows to another block called *effectors*. These are representatives of the muscles. They can be thought of as a kind of *reversed* sensors. While sensors convert an observation of phenomena to internal signals, effectors do the opposite: they translate internally recognized signals to muscle contractions. Sensors observe the world, effectors act upon it. In more general case, effectors can be much more than just muscles, but since the scribe is a human being, we hold this analogy.

Right now, it should be pointed out that the diagram construction between the sensors and the effectors allows for a formulation of something analogous to reflexes, including the ones acquired with time. In such a case, the stimulus goes straight from being noticed to triggering a reaction. Such a reaction could have a varying degree of complication depending on the complexity of the models involved, which perfectly reflects real life observation.

The next element of the diagram to be considered now is the narrator. It is the motor of our mental model, or a master narrating the inner story. This is the part responsible for pulling models from the model storage, placing them onto the model stage (imagination) and putting action on this stage into motion. We will soon explain more specifically what *putting into motion* means; meanwhile, another thing we can say about the narrator is that, in addition to placing models on *stage*, narrator can also be notified about *models* detected by sensors in physical world and it has the ability to observe the *stage of imagination*. The first property is crucial for simulating all the situations which interrupt our inner narrative in real life, like dangerous situations or external calls for attention (e.g. verbal addresses).

The second one is almost self-explanatory: to direct, the narrator has to know what it is directing and how the action unfolds. Although *stage*, *narrative*, *movement* and *action* are useful terms when we are trying to explain the narrator's role, it should be said that in our mental model they are not restricted to their traditional, theatrical meaning. The *action* could be, for example, a running deer or a process of combining models of a lizard with a snake and a bat to create an image of a dragon. Therefore, the narrator's area of expertise is also a combination of the models. Following this line, we can now see that imagining the said running deer can also be viewed as a combination of a model of running with a model of a deer. Another thing to notice is that models in imagination do not appear in all their details at once. Details (or more specific models) appear only when they are needed. It is another task for the narrator to allow for this by a kind of *shifting* its focus between models of differing generality. Combining models, in turn, can also account for the ability to use rules (however were they acquired) in reasoning. In that case, every rule is a model and by combining it with a *tested* model by means of a model of *testing* (binding the two together in comparison) the validity of the second model can be established, yielding a model of an answer in response.

The last element to describe is the model stage. This part is a scratchpad area for the narrator, which we could also call imagination. In this *sandbox*, models are combined together to form more complex structures representing real-life objects or actions. The model stage is also constantly observed by the narrator allowing him to fetch proper models from the model storage, and by the storage itself. This enables the latter to emphasize the known regularities and find new ones within the *scenes* in imagination. It is crucial, for example, for improving methods of work or making scientific discoveries, which can also be viewed as noticing similarities between observed events and other models deemed abstract, like mathematical expressions. Noticing similarity is in fact finding a pattern.

Having described our proposition of the scribe's mental model, we can now use this description as a basis for an attempt to define such terms as *model* and *intelligence*.

When it comes to a model, we could say it is a record of regularity (pattern) or a conjunction of other models which can be used in a narrative. Much of this definition could be supported when we think about how a model could come to life in one's mind. To do that, we should start at the very beginning of human mental development, i.e. at a healthy baby's mind. It could not be a complete *tabula rasa* because from the first hours of their lives, babies are able to express their needs and emotions, even if it is done in a basic way, and have some reflexes specific to them which later in life subside. At the same time, we cannot hope to communicate with them verbally as we would otherwise do. Also, we cannot be sure what thought processes are taking place in their heads because of the said lack of communication and because nobody can remember it from their own infancy. What we can be sure of is that their brains are fed by information coming from their senses. In time, this information gets clustered when a specific kind of stimulus appears again and again. It is the time when the first models are shaped and also the first memories may appear. When this happens it is enough for the brain to remember that a specific model was noticed at a specific time and only a handful of extra, contextual information has to accompany it (possibly as models, too). This is consistent with the brain's extraordinary ability to *compress* information and could be an

explanation why our memories start only at a certain age. Further down the line of development, different clusters are connected together like the word *green* spoken by a mother with the perception of the green colour. This time communication skills are formed and an internal narrative gets enough models to start to work with them. So we start with almost completely sensory information building the first models and follow to develop more complex models with the first ones as a basis. Then we move towards more and more abstract models (ideas), but we still can trace their origins to the first sensory experiences, even if sometimes it is hard to notice it at first. Just as we construct models of our body and the rest of the world using senses, so we create models we could call *expressive* by which we learn to control the motoric abilities of our bodies. By connecting them with sensory models, we establish a critical corrective and coordinative loop allowing us, for example, to learn to walk, talk or do any other activities, including how to make a beautiful book.

We also have to mention such things as emotions, conscience, instincts, preferences and, above all, free will. For now, our model attempts to treat all of them as yet another models, however it is not inconceivable that in the future some of them will have to become independent components. Since we have defined what a memory retained model means to us, we could now attempt to define another term, namely intelligence. A definition of intelligence based on the concept of a model could be as follows: intelligence is an ability to formulate, detect and refine models, store them and combine them to achieve a given goal (also stated as a model). This definition in turn allows us to derive three different kinds (aspects) of intelligence:

- perceptual intelligence – the ability to create a new model if a given situation has not been experienced before, or detect and refine a pre-existing one,
- combinatorial intelligence – the ability to combine known models to achieve a given goal,
- expressional intelligence – the ability to express the desired model with effectors; it could be also called *communicative intelligence*. This expression is by no means limited to verbal skills. It could as well present itself as an ability to work on a manuscript, which can be seen as a manifestation of the scribe's internal mental process.

All these types of intelligence are interconnected in a kind of chain. As everyday observation confirms, an impairment of any of its links impairs intelligence perceived as a whole. On the other hand, it is hard to apply the term *intelligent* to a behaviour based exclusively on one of the said aspects of intelligence. With this final observation, we conclude the description of our proposition of the scribe's mental model.

7. Conclusion

It should be noted that because of the sheer size of the project this paper should be viewed as a starting point of a long and laborious road ahead. In this case, however, any amount of work is balanced by the potential benefits the main of which is the construction of an intelligent book design system even if not matching, then at least aspiring to match the beauty of the old manuscripts. This in itself would be a groundbreaking achievement opening many possibilities.

7.1 Potential applications outside of book design

Although an intelligent book design system is the ultimate goal of this work, it is not hard to notice that the mental model postulated in this paper is not inherently and exclusively bound to the scribal tasks and competencies and has many more potential applications. Since it operates on models and a model is a universal and capacious term, we could imagine it used, for example, as an apparatus translating natural language. The idea does not seem very original until we realize that there are many texts, either poetry or prose, which first have to be well understood within their historical and cultural context to be translated correctly, again, within a proper context. Our mental model places received information on the scene of imagination from which it can be further described, this time using words of a different language and meanings of a different culture. It is much like two persons observing the same situation and relating it in their own tongues.

Another application of this style of a mental model (or a *mental machine*) would be programming. From the beginning of the art and craft of programming, people have been trying to close the gap between the spoken language, which is the most natural tool for the man to use, and an internal language of machines. Despite these efforts, new programming languages which have been developed do not change much in that regard. Our mental model may provide a framework by which a machine could be able to *understand* the task described in a natural language and propose a solution. If this solution is not satisfactory, it will be corrected using the very same language. That kind of programming would be similar to explaining to another person what we want them to do. Natural, spoken or written, language would not be the only type of *language* available; as in the real-life situations we would be able to pass the necessary information using, for example, gestures or drawings.

Possible applications of the scribe's mental model are plenty. To enumerate them would be too much for

this paper, but we could say that it could help to realize things like some psychological simulations, provide life-like gaming environments with intelligent virtual players, allow for the on-the-go creation and modification of computer graphic user interface, making it a breeze to match to personal preferences, or to be used to prepare a beautiful map shading, worthy of the name of a piece of art.

7.2 Relation to other work

Our work is not the only one in the field concerned with human mind inner workings in relation to the tasks a human being performs. One of such works is the work by Shao and Terzopoulos (2007), which presents a very detailed and complex simulation of human behaviour in an urban environment such as a train station. It builds a virtual world consisting of a train station filled with people. Each of the *persons* in the simulation is given their own simplified *mind* which is to guide their actions. The said mind keeps track of such human-like attributes as being curious, tired or thirsty. It contains a person's knowledge, memory, motion repertoire, and allows the senses to gather information about the environment and the *motor interface* to facilitate the movements in it. It also plans each person's actions adapting them to the situation at hand, which is crucial in a scenario when the simulated person has to, for example, move through a crowded hall to reach a ticket line. It can also make a person sit when they are tired or seek a drink when they are thirsty. All of that makes for a stable and quite life-like simulation of a train-station.

Impressive results of the Shao and Terzopoulos' simulation are matched by the equally impressive effort put into its preparation. The most interesting part of it, for our purposes, is the pedestrian model devised for the simulation. This model is presented in a quite sizeable diagram from Figure 10 in Shao and Terzopoulos' (2007) paper. Originally this diagram, which we use as a basis for our Figure 6, depicts components of both pedestrian model and world model along with their interdependencies and interactions. All of these are used in a single time step of a simulation designed by the two researchers. Such step is called HSS or *human simulation step*. In it all of the components are visited and used in a specific order to update pedestrian and world states. *Memory* on the diagram represents a list of pedestrian goals – like: wait for somebody, get a drink, etc. *Knowledge* corresponds to an internal image of the pedestrian's world with its objects, topography and events. *Cognition* binds memory and knowledge together for the sake of planning actions by the *Cognitive Control* component. *Cognition* influences *Behavioural Control* that is a component responsible for issuing general commands to *Motor Control Interface* (like: look at the clock, sit down, etc.). *Motor Control Interface* in turn tunes down unrealistic commands taken from *Behavioural Control* (e.g. the latter commanded the pedestrian to move with a speed physically unattainable by a human being) and manages pedestrian's body by selecting one of the options from the so called *Motion Repertoire* (predefined movements). Movements of the pedestrian's body are registered in an updated *World Model* and influence *Sensing*. *Sensing* then perceives current situation in *World Model* and allows *Knowledge* to be updated accordingly. *Sensing* also acts as a kind of transducer for so called *Internal States*, which represent pedestrian's condition by the use of parameters like tiredness, thirst or curiosity and may influence *Cognition*.

After a while it is not hard to notice interesting similarities between Shao and Terzopoulos' diagram and our own diagram from Figure 5. The big difference, however, is the complexity. All of the separate abstractions used to build the pedestrian model relate more or less directly and precisely to one of the abstractions used in our model of the scribe's mentality. These relations are presented in Figure 6, which contains the original diagram from the Shao and Terzopoulos' article connected to our own diagram from Figure 5. Knowledge, memory, motion repertoire and partially internal states can be mapped to our model storage. Behavioural control and some aspects of internal states find their counterparts in the model stage. *Sensing* and *Motor Control Interface* are pretty much directly equivalent to our sensors and effectors, respectively. *Cognitive Control*, in turn, is quite similar to the narrator used in our case to build the course of actions. *World Model* and *Rendering* are roughly the same as our *World*.

The similarities and differences between the two diagrams allow us to hope for two things. Firstly, if there is a working model, based on assumptions similar to our own, it makes future practical implementation of our model all the more probable. Secondly, since much of the complexity of the pedestrian model can be potentially *compressed* in our model, it lets us be cautiously optimistic about our model's spectrum of applicability and universality.

7.3 Plans for the future

Plans for the nearest future consist of further development of the mental model and its parts presented here. Such parts in need of further investigation are models themselves and ways in which they can be combined by the narrator. We have to look more closely on how the models can be represented, what are their attributes and how they relate to each other. The narrator and its role also has to be more fully understood and described. The next step would be a system complete with examples of models realizing a scenario in which a page of a book is designed. This hopefully will allow us to properly assess the soundness of the whole project, identify problems and decide on the next course of action to take.

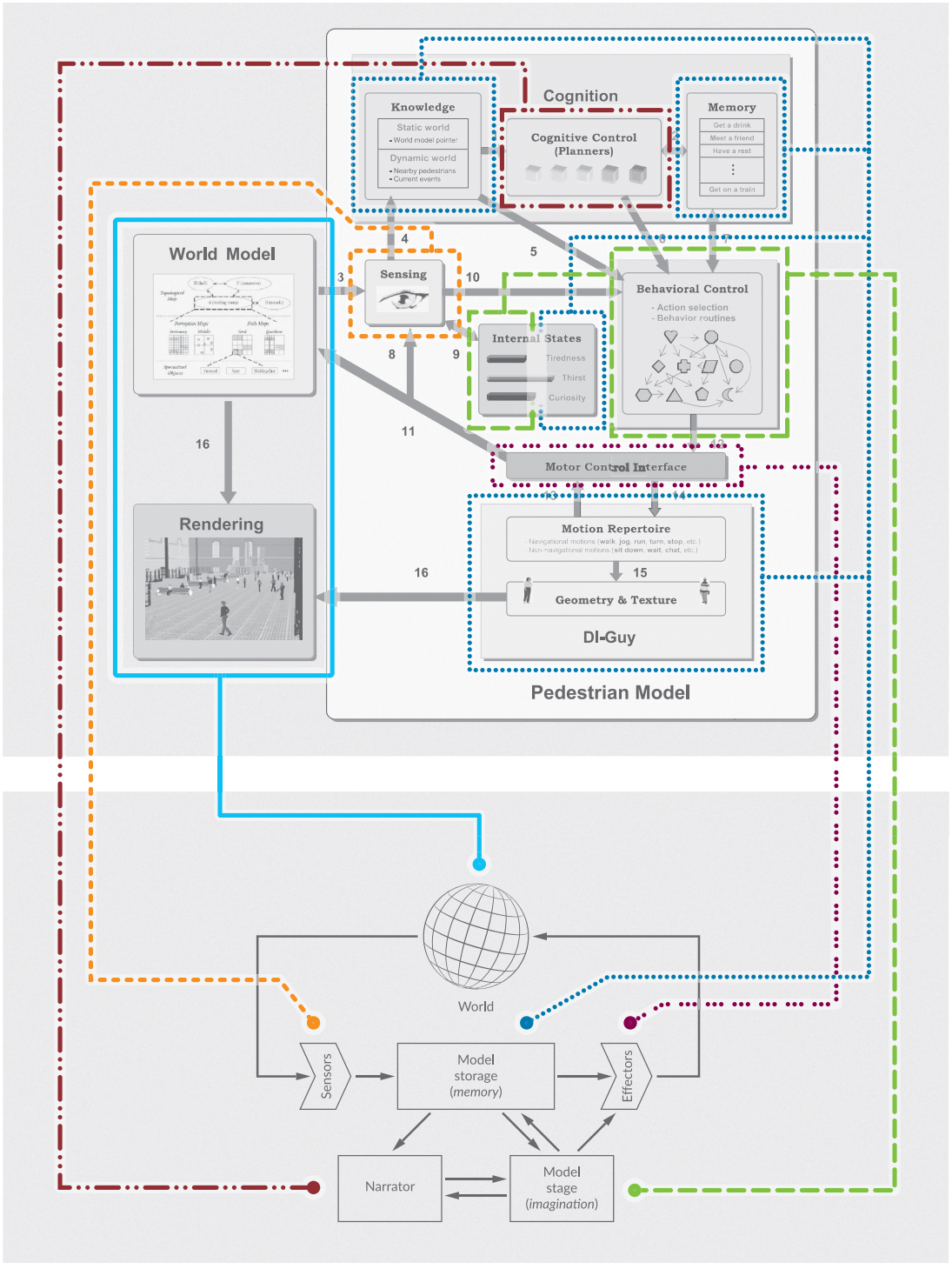

Figure 6: Scribe's mental model in relation to the diagram from the article by Shao and Terzopoulos (2007, p. 258)

Endnotes

This paper presents State of Art of Mr. B. Szczurek PhD dissertation under T. Szuba supervision. Paper also fulfils PhD program requirements of Computer Science Department at Faculty of Computer Science, Electronics and Telecommunications, AGH University.

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References

Adobe, 2016. [online] Available at: < http://www.adobe.com/products/catalog.html> [Accessed September 2016].

Aquinas, T., 1920. *The "Summa Theologica" of St. Thomas Aquinas, Part I QQ I.-XXVI.* (Literally translated by Fathers of the English Dominican Province). London: Burns Oates and Washbourne.

Clark, K., 1977. *Civilisation, Chapter 1: The Skin of Our Teeth*. London: British Broadcasting Corporation.

Craik, K.J.W., 1943. *The Nature of Explanation*. Cambridge: Cambridge University Press.

Frutiger, A., 1989. *Signs and Symbols: Their Design and Meaning.* (Translated from German by A. Bluhm). New York: Van Nostrand Reinhold.

Girard, A., 2016. *The Carthusian Order.* [online] Available at: <http://www.chartreux.org> [Accessed September 2016].

Johnson-Laird, P. N., 2004. The history of mental models. In: K. I. Manktelow and Man Cheung Chung, eds. 2004. *Psychology of Reasoning: Theoretical and Historical Perspectives*. New York: Psychology Press. pp. 179–212.

Johnston, E., 1906. *Writing & Illuminating, & Lettering.* New York: Macmillan.

Kurzweil, R., 2012. *How to Create a Mind: The Secret of Human Thought Revealed*. New York: Viking Penguin.

Lacroix, P., 1875. *The Arts in Middle Ages and at the Period of The Renaissance*. London: Chapman and Hill.

Leslie, S.E., 1909. Lessons in business writing. *The Business Educator*, 14(5), p. 9.

Licklider, J.C.R., 1963. *Memorandum for: Members and Affiliates of the Intergalactic Computer Network*. [online] Available through: Kurzweil Accelerating Intelligence website <http://www.kurzweilai.net/memorandum-for-members-and-affiliates-of-the-intergalactic-computer-network> [Accessed 15 March 2016].

Microsoft, 2016. [online] Available at: <https://www.microsoftstore.com/> [Accessed September 2016].

Oliver, R., 2015. *The Cistercians.* [online] Available at: <http:// http://www.osb.org/cist/> [Accessed September 2016].

Oliver, R., 2016. *The Order of Saint Benedict.* [online] Available at: <http://www.osb.org> [Accessed September 2016].

Putnam, G.H., 1896. *Books and Their Makers During the Middle Ages*. New York: G.P. Putnam's Sons.

QuarkXPress, 2016. [online] Available at: <http://www.quark.com/Products/QuarkXPress/> [Accessed September 2016].

Schmidhuber, J., 2009. Driven by compression progress: a simple algorithmic theory of subjective beauty, novelty, surprise, interestingness, attention, curiosity, creativity, art, science, music, jokes. *Journal of SICE*, 48(1), pp. 21–32.

Shao, W. and Terzopoulos, D., 2007. Autonomous pedestrians. *Graphical Models*, 69, pp. 246–274.

Splendor, 2016. *Pro Deo et Ecclesia: Proclaiming the Beauty, Grandeur and Majesty of the Church.* [online] Available at: <http://thesplendorofthechurch.com/2016/09/06/refuting-the-born-again-arc-heretic-on-bible-history-and-private-interpretation-by-splendor1618/> [Accessed September 2016].

Thagard, P., 2010. How Brains Make Mental Models. In: L. Magnani, W. Carnielli and C. Pizzi, eds. 2010. *Model-Based Reasoning in Science and Technology*. Berlin, Heidelber: Springer. pp. 447–461.

The Grid, 2016. *The Grid.* [online] Available at: <https://thegrid.io> [Accessed 20 March 2016].

The Next Rembrandt, 2016. *The Next Rembrandt.* [online] Available at: <https://www.nextrembrandt.com/> [Accessed 12 April 2016].

Tillotson, D., 2016. *Medieval Writing.* [online] Available at: <http://medievalwriting.50megs.com/writing.htm [Accessed 12 March 2016].

Turing, A.M., 1937. On computable numbers, with an application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, ser. 2, 42(1), pp. 230–265.

Tymms, W.R. and Wyatt, M.D., 1860. *The Art of Illuminating as Practised in Europe from the Earliest Times.* London: Day and Son.