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Foundations for Spread Page: review of existing concepts, solutions, technologies capable of improving effectiveness of conveying knowledge

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Spread Page is our code name for a new, more efficient way of conveying technical information and scientific knowledge – freed form the text-centered mindset and focused on graphical, interactive, multidimensional representation. The article presents an overview of current concepts and solutions that seem applicable in crafting the idea of Spread Page. In our discussion we begin with novel, abstract, organizational ideas regarding the process of creating and disseminating scientific knowledge, that break up with the traditional model of (paper) publishing. Then we turn to analyzing methods and conventions used in (graphically) modeling real and abstract constructs, and finally review existing software solutions, technologies and exemplary, concrete products that implement certain functionalities instrumental to our cause. We reach the conclusion that, in certain areas (dealing with read-world entities, e.g. mechanics or anatomy), such desired "Spread-Page" way of representing knowledge is already within our reach. In more abstract fields, like law and legislature, political science, etc. we are still far off, mostly due to lack of appropriate standards and (graphical) notation. The paper is as a part of a larger set of articles presenting the proposed concept of Spread Page.

Keywords: graphical knowledge representation, Spread Page.

1. Introduction

Spread Page is our proposed name denoting concepts, technologies and solutions aiming at representing content in a new way: one that would leverage existing technological capabilities and replace text-based documents. It was initially proposed in "Spread Page Initiative Manifest" [3] and then elaborated on in e.g. [4]. The bottom line of our assertion presented there is that in light of recent technological advancements in electronic devices (tablets with touchscreen, impressive computational power, rich multimedia capabilities, prospective 3D displays, tactile feedback and much more) it is becoming deeply inefficient to keep imparting scientific knowledge by means of static, text based documents (books, articles); it is time to move on.

Writing – making the spoken words persistent – was among the most important inventions of all times, but today we feel that its terminal moments are about to arrive, and for a reason. With written text, there is an upper bound (a baud rate, so to speak) to the amount of knowledge that can be passed across, from one mind to another. Numerous fields of science and technology have already recognized this limitation and turned to area-specific, more efficient notations, exemplified briefly in chapter 3. In many others, however, text based documents remain to be the default, predominant yet increasingly problematic (think e.g. of law and legislature, and todays nearly insane rates of producing voluminous legal documents). It is our strong belief, that hanging on to written text will increasingly hold us back. It is time to do away with paper centered mindset.

Of course, the first steps have already been taken as electronic documents almost completely replaced traditional ones, "based on hardware" (be it paper, parchment, earlier on, or clay tablets some time before that). The last remaining reason for printing out physical documents is to have them officially signed, e.g. by parties of an agreement. However, with electronic signature technology becoming widely available even that function of paper is becoming obsolete. Similarly with books: virtually all current prints are released both electronically and in paper, and – due to obvious cost advantage and proliferation of electronic devices – eBooks are gaining the upper ground. In fact, it becomes increasingly common, that the electronic version is the only one available, which has been typical for scientific periodicals for a while, but today also fiction starts to follow suit (as it is the case with e.g. [5]).

But by itself, switching from paper sheets to glowing glassy panels hardly changes anything. In too many cases, electronic documents follow the old paper-centered mindset and in the end, we essentially get the very same thing, only seen on a digital screen. There are noticeable advantages, of course, in weight of things to carry around and in ease of use, but it is hardly the point. There is much more to come, much further to go. Capabilities of electronic devices make it possible to make "books" interactive, time-varying, multidimensional, layered, multi-resolution, aspect-oriented, user-aware and much more.

In fact, there are already numerous concepts, standards and tools that provide just that: content, that goes far beyond flat and mute text in all the respects just mentioned. These solutions lay the foundations and pave the way for the future of scientific literature. Or perhaps, not "literature" any more, but some content conveying means, containers and standards deserving their own, new name (and our proposed codename is "Spread Page"). The purpose of this article is to review these foundations: current ideas, technologies, solutions, etc. that have already forced us to reconceptualize our notion of a document going far beyond its traditional meaning. The following chapter discusses conceptual shift in organizational and legal aspects of creating and disseminating knowledge which tends towards marginalizing the traditional scientific journals. Chapter 3 gives an overview of the topic of graphical representation of information and knowledge. The following, chapter 4 reviews existing computer tools and technologies making practical use of those graphical representations. Finally, chapter 5 concentrates on related, modern user interface technologies providing Rich User Experience, prospectively, with elements of user-awareness. We conclude the paper with the attempt to point out the most lagging areas needing more urgent attention on the way to Spread Page goals.

2. Conceptual and organizational novelties in sharing knowledge

With the long tradition of (paper) articles and books we are strongly accustomed (if not: addicted) to certain features of documents, like its form defining clear boundaries, explicit and concrete (set of) authors and nonmutable content – once it is published it does not change (unless it is revised in preparation of new edition). Scientific literature is still dominated by periodicals with paper-like articles (in pdf format) which follow virtually the same production cycle as the "good old" paper publications. It may seem, that all various digital technologies available to us today did very little to change the centuries-old mechanism of sharing knowledge. Yet, alongside these traditional journals, there are significant changes and novelties within organizational, practical and even legal aspects of creating, presenting and disseminating knowledge.

As argued, by the authors of [6], we are about to witness "second scientific revolution" and the traditional ways are going to fade away. One aspect of this change, already present in scientific periodicals, is the growing emphasis on non-textual content that comes with published materials. Releasing raw data and/or software's source code, on which articles' findings are based, is highly desired and increasingly encouraged as it enables other researchers to reproduce the results (and follow up). Notably, adequate platforms for sharing research data have promptly, symbiotically emerged (e.g. Mendeley Data service, [7], or DataCite, [11] – a "citable data" service). Some journals have yet already gone further in that direction, making the thematic data an integral, required part of a publication. *Journal of Maps* [9], is just one such example, where it is the geographic information (charts, diagrams, interactive maps, spatial simulation results, etc.) that constitutes the essential part of the "article", while text-based papers are only to provide auxiliary description and explanation.

Secondly, and perhaps more importantly, the proclaimed "second scientific revolution" manifests itself in breaking up with traditional ways of creating and sharing knowledge – i.e. those revolving around publishing of articles and monographs – and turning towards novel ways. Already today, next to respected journals with old-style articles, there is a whole spectrum of alternative organizational and technical solutions:

- preprint servers (with arXiv [8] created as early as 1991, being probably best known. Since then numerous others were launched, e.g.: PsyArXiv, AgriXiv, SocArXiv, engrXiv), which are "Journal-like" in the sense that the presented content resembles articles, it is reviewed (i.e. someone takes a look and accept an article before it goes life), publicly "discoverable" and available and authors get credit for authorship (DOI, ORCID). Most preprint servers allow for ancillary files (datasets, code) with articles;

- self-publishing services (Lulu [13], Amazon's CreateSpace [12]) are in turn such 'semi-publishers' with respect to books, where an author has a wide range of options – from 100% do-it-yourself track at symbolic costs to wide list of paid services typical for 'real' publishing houses: editing, layout & design, marketing, etc.;
- social networking systems (Academia.edu, ResearchGate – both attempting to become "the facebook for scientists") come next, as platforms for disclosing and sharing preliminary solutions, work-in-progress, etc.;
- blogs and vlogs (video blogs) where authors share various posts, with the hope that others would find them informative and helpful; the posts usually deal with ways of using certain tools of technologies (think e.g. of numerous visual tutorials published on YouTube);
- discussion forums / message boards are then used for even less formalized exchange of thoughts, usually focused on some detailed technical issues (like StackExchange, being an example of Q & A community with crowdsourced moderation, peer-rating, reviewing mechanisms, etc.);
- collaboration repositories and platforms allowing for crowdsourced creating and sharing of knowledge, usually featured with version control, peer-reviews etc. Examples include GitHub or Wikipedia.

Arguably, today journal articles are hardly ever the first place to look in search for scientific knowledge. General topics are described well enough on Wikipedia, specific issues can often be found in YouTube tutorials or worked out through StackExchange (or other science related social networking sites), information about most recent advancements in research can be found in documents stored on preprint servers or in scientists' blogs. On top of that, these alternative sources are usually easier to get to and use (thanks to open access and/or friendlier public licenses) and more interactive (featuring rich media content, discussion forums).

It all shows that the static paper-like article does not have to be the only, nor even the most important "knowledge transferring vehicle" for science and technology. There are no fundamental barriers (organizational, technical, legal) due to which a publication could not be *something* arbitrarily different from a pdf article. Something, that will include data or logic (code scripts), rich media, interactive content and maybe even… text, occasionally. Finally, there is no fundamental reason why it couldn't be created with crowdsourcing/collaborative authoring and available through open access. "In the future, online research literature will, in an ideal world at least, be a seamless amalgam of papers linked to relevant data, stand-alone data and software, 'grey literature' (policy or application reports outside scientific journals) and tools for visualization, analysis, sharing, annotation and providing credit." [1].

3. Graphical (re)presentation(s) of (information and) knowledge

But how should such "seamless amalgam" look like? In what shape is the body of knowledge? We are all well aware that knowledge is a structured, multidimensional entity with numerous scientific and technological fields, overlapping and interconnected in various ways – which stands in sharp contrast to one-dimensional, linear text that we still so heavily use to transcribe it. Notably, the field of Knowledge Representation is hardly a new one and for quite a while it has been providing good guidance in answering these very questions – about ways to model, describe or visualize knowledge.

It is important to point out, that the topic of Knowledge Representation actually contains two (semi-)separate notions – machine-oriented and human-oriented. The former constitutes an area of Artificial Intelligence which aims to make knowledge accessible and actionable to machines (e.g. to the point where a computer could inference/prove new information form a set of known facts) with the ultimate goal that a computer may actually understand our knowledge (minding all reservations about what it actually means to "understand") or create new one. The latter is an interdisciplinary field, just as easily attributable to computer science as to ergonomics or perhaps even psychology, and works on methods and tools to present complex, dynamic information in a form easily graspable and actionable by humans. So to speak: it is about designing the "knowledge-human interface" to be as efficient as possible. This second area is what we are solely interested in, here, although the two are probably more interconnected that it may seem at first (in line with the premise that a machine needs to have some understanding of knowledge in order to present it understandably to humans).

There exist quite a few domain-specific standards for graphical (modeling and) presentation of information, closely tied to the specifics of a given field. To our mind, it is instructive to divide them into two contrasting areas, dealing either with real-world or abstract constructs:

- real, physical objects are (at most) three-dimensional and their composition is based on well-defined spatial relationships (on top of, inside, East of). Examples of fields implementing domain-specific notations include: cartography, anatomy/medicine, mechanical or civil engineering, military tactics, etc.;
- abstract entities, in turn, may be described in terms of arbitrarily many 'dimensions'; their building blocks may have arbitrary layout and be interconnected through any number of abstract relationships – without any spatial or geometric meaning. Some subject matters in this category make extensive use of standardized graphical notations, e.g.: software engineering, operations research, management, economics, mathematics. Other fields mostly stick to plain text (law/legislature, philosophy, psychology).

Somewhat on the border are cases where structures made of real objects are represented with abstract notations, like e.g. in chemistry or electrical engineering, where the actual spatial layout of building blocks (electronic pieces within a circuit or atoms within an organic molecule) is secondary with respect to their relational properties, i.e. "what is connected to what and how". Such relationships are easier to show with abstract schematics and hence circuit diagrams look nothing like electronic printed boards while chemical formulas hardly resemble shapes of actual molecules.

Naturally, the first case, when the visualization relates to real-life objects, is significantly easier. For once, human brains are built and trained to operate in three-dimensional space and interact with 3D objects. Spatial properties/relationships (on top of, goes through, etc.) are highly intuitive and easily depictable on drawings; paper representations of such objects can be made to resemble the look of the actual thing. In addition, fields like cartography, architecture or anatomy have much longer history than, say, software engineering and simply had more time to polish their standards to perfection. Let us note two key lessons learned from modeling real world objects, that later become even more important in depicting abstract entities. It turns out that in order to enhance comprehensibility:

- it is better to give up photorealistic presentation in favor of standardized symbolic notations, color coding, etc. (e.g. for most purposes satellite images are much less informative than thematic maps);
- the same object can (and should) be depicted in a number of different ways, exposing its different aspects, e.g.: technical drawings present the same device on complementary views (three orthographic projections, perspective, exploded, cross-sectional view, cutaway drawings, etc.), in a geographical atlas the same area is presented on a number of thematic maps: topographic, political, climate, economic, etc.

This way the object of interest can be adequately presented, even if it is composed of multiple elements coming about in many complex configurations and/or relationships.

For the more challenging area of representing abstract constructs, the two above points became of paramount importance. First of all: abstract notions have no physical shapes (after all: how does "monetary inflation", 'software module' or "danger" look like?) and relationships among them – equally abstract – lack any clear geometric analogies or interpretations (e.g. think of geometric meaning of "A obeys the laws of B" or "A owes money to B"). In consequence, graphical notations in abstract fields are usually pure conventions composed of arbitrarily chosen symbols and spatial layout rules – often based on relatively random connotations with real-life objects (e.g. danger having the shape of a yellow triangle). Secondly: due to multitude of aspects and dependencies within such entities (think of complex computer systems or national economy) they simply cannot be completely (and readably) depicted with just one graphical representation. Hence, many perspectives drawn on diagrams of different kinds are necessary to show all the various aspects of the same thing.

Without much exaggeration, it may be stated that there is almost a whole branch of science dealing with abstract graphical notations (outstandingly reviewed in [2]) whose generally agreed goal (at least in theory) is **cognitive effectiveness** – defined as "the speed, ease and accuracy with which a representation can be processed by the human mind" ([24]). It turns out, however, that in many cases practice hardly follows the enlightened theory – numerous notations are based on intuition and aesthetics rather than proven effectiveness (topic discussed in depth in [2] with respect to notations used in software engineering). This way numerous fields ended up with notations where out of a number of visual variables (six, according to [25]: shape, size, color, brightness, orientation, texture) only shape is really used to convey actual semantics. And even that is done poorly – the shapes are overly simple and with little variability (mostly rectangles, sometimes with decorated or rounded corners, and ellipses). Such notations are extensively used in a wide range of fields, with good examples being:

- software engineering, as already mentioned, currently dominated by UML – "a visual language for visualizing, specifying, constructing and documenting software intensive systems" [26], although several alternative notations are also in use e.g. in Data Flow or Entity Relationship Diagrams;
- systems and control theory, in which dynamical systems (with or without control) can be graphically represented in a number of alternative notations: traditional Block Diagrams, Causal Loop Diagrams and Stock-and-Flow Diagrams within the System Dynamics methodology, or ModelicaML (derived from UML/SysML and mapped to model's textual representation in Modelica), etc.
- management, with such key areas as modeling of business process (with BPMN or similar notations) or representing and tracking projects (e.g. with PERT/CPM or Gantt charts). Another important area in management control is Business Intelligence – Visual Analytics which aims to optimize presentations of massive, complex data through novel visualization techniques (e.g. treemaps, [28], for displaying non-spatial, attributed data with hierarchical structure).

The great majority of notations, including the relatively modern ones, are still deeply rooted in 2D, paper-centered mindset – flat, simple and static. Many of them were designed for drawing models with pen-and-paper, and hence cognitive effectiveness was subordinate to the ease of sketching by hand. But today no one needs to do that anymore and it is actually more likely that a person has in his packet an electronic device with touchscreen, than a pen and a paper notebook (an IT person, at least – the authors have verified this claim on themselves, on numerous occasions).

Sticking to flat notations seems to be mainly a matter of inertia, as there are already numerous proposals to introduce 3D spatial diagrams. One interesting example discusses ways of extending treemap into the third dimension to enhance its informational capacity – not only due to the plain use of the extra dimension but also thanks to new opening possibilities to use shape, shading, transparency, texture, shadowing, silhouette enhancement techniques, etc. to fit more facts on the same graph (see e.g. [14], [15]). Similarly, a number of authors postulate to move towards 3D diagrams in software engineering practice (e.g. in [16], [17], [20]; see also an interesting animation at [19] demonstrating the potential of animated 3D UML). Further examples could easily be given; the ideas are already out there.

In that light, we believe that it is both viable and desirable for abstract notations to catch up with the ways currently specific to 3D modeling of physical objects. Then, as a next step, we see it as a possibility to apply one, uniform way of perceiving and modeling all constructs: physical, abstract or hybrid (i.e. having both aspects). Such modeled entity could be defined as a set of inter-related elements residing in a multidimensional space, of spatial, temporal and logical dimensions. The internal relations among components could, again, have spatial, temporal, abstract or, possibly, mixed nature. Assuming, that all dimensions could be treated uniformly, at least to a degree, it should be feasible to render visually meaningful views build for arbitrarily chosen dimensions, even with mixing-and-matching spatial, temporal and abstract aspects. With such modeling framework, it could become more natural to use graphical notations in areas today dominated by text, like law, political science, philosophy etc. Although today we neither have adequate notations and standards nor experiences and practice needed to construct multidimensional, graphical representation of, say, international treaties, scientific theories or national economies, our intuition suggests that, in principle, this is possible. And it is also **desirable**, as today these domains really start to groan under the weight of countless pages of text.

4. Technical aspects: current tools and technologies

The numbers of available computer applications are vast and rapidly growing, making the field hard to embrace. Even if we put aside computer gaming and concentrate on tools dealing clearly with creating, editing and presenting information (plus persisting it with specifically formatted disk files – "content containers") it is still an abundant area. Without claiming, that it is the best ever classification, we propose the following as on serving well our needs. For our purpose we divide available computer tools into three rough groups, where the mode of presentation is predominantly:

- linear, text based – being the closest relative of traditional books and articles;
- (up to) three-dimensional – dealing with models of real-world, physical objects;
- in abstract "space" defined by arbitrary, logical dimensions and relations – for modeling abstract constructs;

bearing in mind that the division and distinction might at times be far from clear or obvious.

Text-based form

In this category, the presentation of electronic content most closely resembles the traditional, paper-based approach. Even today, in typical uses of the most popular applications (Microsoft Word or Power Point, Adobe Acrobat Reader, a web browser displaying static webpage) the displayed content (of a doc, pdf, html or other such file) could almost just as well be read off a piece of paper. Fortunately, we already are moving away from static text, towards content experienceable in live, interactive and multidimensional ways.

One key feature is enhanced, interactive browsing through the content's structure. Most commonly, the structure is hierarchical (i.e. based on the composition, or "whole-part" relationship) and one-dimensional – constructed as linear narration divided into chapters, which are composed of subchapters (which are then composed of sections, etc.). A reader can fold–unfold chapters and sections and quickly navigate to the interesting part (a word processor in outline view, PDF reader showing navigable table of content, foldable elements and hyperlinks within webpages). Noteworthy, in some presentation applications (e.g. Prezi, Sozi or Impress.js) the hierarchy is not linear, but planar, therefore reading and presenting the content uses two-dimensional navigation plus zooming-in and out. Two dimensions is, however, as far as it currently gets – the presented content is confined to a planar page that does not spread into higher dimensions (as in categories described later on). In addition to composition, also other relations between document's elements may be present and important which in effect defines a complex, network-like structure of interlinked, cross--referenced parts (think: Wikipedia).

Another enhancement in interaction with information, unavailable on cellulose, is present in "computable documents" going much farther than automatic text formatting or autonumbering of chapters and lists (although that also requires some computation). In such documents, the information presented is calculated on the fly, based on mathematical formulas or logical rules defined by the user. The generated results may have numerical or textual forms but also graphical and/or animated. Simple mathematical functions (such as summation) are actually available in tables in most popular word processors (e.g. Microsoft Word or OpenOffice Writer) but better examples of computable content provide spreadsheets (Excel, Calc) or scientific computing environments such as Wolfram Mathematica or MathCad. Also, similar end can be achieved with embedding appropriate active controls within html pages.

Finally, numerous applications in this category allow the user to embed almost any kind of rich media, such as sound clips, animations or other interactive controls (example technologies include ActiveX, AJAX, SilverLight, Flash, etc.). Such documents are not created with printing in mind, anymore, but for viewing on electronic devices. Paper deprives them of their key features.

Physical-(3D) space-based realm

Graphical representation of knowledge about real-world objects was already touched on in the previous section. The notations and standards mentioned there are implemented in numerous computer tools falling into the two general categories:

- 3D modeling and CAD (Computer Aided Design) tools (where CADs can be seen as dedicated 3D modeling environments geared towards specific engineering applications) such as: 3DS Max, Maya3D, Blender, SketchUp, Catia, AutoCAD, Autodesk Inventor, SolidWorks or TurboCAD, just to name a few;
- GIS (Geographic Information System) providing the functionality of digital maps, e.g. ESRI ArcGIS, Autodesk Map3D, Intergraph GeoMedia, GRASS GIS.

Although the border line is not as sharp – e.g. CAD tools used in civil engineering necessarily refer to the underlying terrain (and for instance, Map3D is actually a very close relative of AutoCAD) while presentation of terrain with

GIS maps often offers 3D viewing capabilities (e.g. on Google maps, note also streetView®) similar to those in 3D modeling tools.

Computer technology did not necessarily change the look of the presented information – a GIS map usually still looks like a map, CAD engine drawing still looks like an engine drawing – but in other respects it introduced dramatic improvements. Here too, compared to paper days we have gained interactivity, computability and animation. Both during creation and viewing of a model (3D object or a map) the user is exposed to interactive "canvas-space" with the ability to zoom in or out, rotate the angle of view, select specific elements, turning on/off visibility of components or layers. This way a user can define views suiting most specific, individual needs (e.g. make engine chassis transparent to see internal parts, filter out roads not suitable for buses) or choose among many predefined thematic views (satellite photo, topographic, population density). The computability feature, in turn, may be exemplified with such functionalities as (for CAD tools) calculating mass, moment of inertia, flexural strength, etc., or (for GIS tools) evaluating potential flooding areas, finding shortest routes between locations and more. Finally, numerous tools allow for designing animated presentations of the model and then generating movie clips e.g. for showing a working piston engine (or dancing Mickey Mouse, for that matter).

Abstract-space domain

Representation of abstract, multi-dimensional information with graphical notations becomes increasingly important, as it was already briefly discussed in the previous section. That area has also been heavily computerized in numerous and diverse fields. Obviously, within the space given it is impossible to give a complete overview of the topic. Instead we will concentrate on some specific yet illustrative domains – software engineering, workflow modeling and business intelligence.

Software development today is widely supported with CASE (Computer Aided Software Engineering) tools. Most powerful applications (such as IBM Rational Software Architect Designer, RSAD) aim to provide complete support: from drawing loose sketches for initial conceptualization through use of formal UML diagrams for modeling and tracking requirements all the way to deployment of concrete, executable software modules. In line with the idea of model-driven development, such tools are capable of generating programming language code and/or database schemas based on their graphical specification. In addition, they ensure accurate synchronization between models and code: changes made graphically are reflected in source code, while changes made textually in code are reflected back in UML diagrams. This way, the same product – a software system – can be shown and edited with a number of different views and perspectives: from general, graphical to specific, textual or tabular.

An important use of graphical notations is business process and workflow modeling which, in a way, bridges the gap between management and software engineering. It turns out that very similar functionalities, dealing with modeling workflows are implemented in vastly different tools: from applications typically associated with software development whose functionality widened towards implementing workflows, through ones dedicated solely to business process modeling and simulation for the purpose of optimizing company's operations, to full--blown ERP-class systems where workflow editors are used to orchestrate operational tasks. Examples from the first group may include IBM RSAD (mentioned earlier) or Microsoft Visual Studio which integrate with corresponding deployment and execution platforms (IBM WebSphere and Microsoft Windows Workflow Foundation, respectively). The second tier may be exemplified with ARIS or Bizagi BPM Modeler, while third with SAP Business Workflow (SAP WF) or Oracle Process Manager. Notably, functionalities of tools in these groups become increasingly overlapping and/or integrated (for instance, models developed in ARIS can be transported to SAP). In most cases the user starts with defining a business process then can simulate and tune its performance and finally deploys it onto a platform to be executed and tracked in production environment. The notation used most often is based on BPMN, a de facto standard in the field.

In management, setting up operations is just as important as evaluating company's overall performance. Here, too there are significant advancements in integrating visualization with powerful computational, analysis tools. Business Intelligence technologies lean towards Visual Analytics whose goal "… is to facilitate [visual] analytical reasoning process through the creation of software that maximizes human capacity to perceive, understand, and reason about complex and dynamic data and situations" [27]. Online analytical processing (OLAP) deals with analyzing in (near) real time, multi-dimensional data queried from company's databases (or other sources, e.g. data warehouse). OLAP analytical operations deal with:

- "slicing and dicing", i.e. selecting the desired aspects / dimensions – e.g. geographic, temporal, by market sector, client profile, product kind,
- consolidation, dealing with aggregating detailed data within selected dimensions,
- drill-down, the opposite to consolidation, aiming at uncovering details.

Interestingly, these operations have their near equivalents in ways of manipulating digital maps (in GIS), i.e. respectively: selecting thematic layers, zooming out and zooming in. This analogy demonstrates the potential for seamless integration of analysis and visual techniques where GUI actions intuitively correspond to defining or adjusting complex analytical queries.

An important ongoing trend present among the tools discussed above heads towards integrating all above functionalities within one software suite, as it is the case, for instance, with the most powerful ERP-class systems (SAP, Oracle E-Business Suite). At operational level they provide functionality for defining workflows within business processes and then deploying, executing and tracking them. Higher up, they are capable of performing interactive OLAP analyses of most various aspects of company's operations. At the top, executive, level there are functions for generating most general reports – often in the form termed as "business dashboard" or "management cockpit" where graphs and gauges display performance measures (KPIs) computed from and progressively updated in sync with massive amounts of underlying business data. On each level, wherever practical, an applicable graphical, interactive representation of the information at hand is used.

The presented examples suffice to point out some common traits and trends:

- represented entities are multidimensional complex, and featured with numerous relations among its composing parts;
- different perspectives can be chosen through selecting aspects (choosing cross-section) and level of aggregation ("zoom");
- software packages offer computational support for going both-way between graphical representation and actual data: e.g. user's diagram defines a process to be simulated or (vice-versa) presented diagrams are generated based on complex analyses of underlying data,
- graphical notations and visualization techniques are still revolving around two-dimensional diagrams, graphs or gauges with scarce use of 3D graphics or animation.

There are, actually, interesting pioneering applications extending abstract notations into 3D (examples may include GEF3D [29], X3D-UML [18], or graph visualizing packages like Gephi or Cytoscape) but mostly they are narrowly focused and/or in prototype/incubation stage.

Unfortunately, in other areas we lack mature tools providing visual representations and interfaces allowing to dig through the complexity of the matter at hand. One especially engaging example is law & legislature – a field literally sinking in abundant mass of textual documents. Naturally, there are computer applications to support the field professionals such as Lexis Advance [36] and Lex – Wolters Kluwer [37] (or for regular citizens: LII [33]) which offer numerous functions: categorization of documents, browsing through their structure, bookmarking, advanced text-based search etc. but never-the-less it is all based on the traditional textual format of legal documents. The situation seems to be bound to change as there are already interesting proposals for "visual law" and, to an extent, computable law, as reviewed in [31] (dealing e.g. with rewriting Canadian law in a way more visually and linguistically friendly [32], devising visual aids for law comprehensibility, [34], or The State Decoded project providing access to US state laws transcribed in JSON format accessible to software, together with open source solution for accessing the legislative repositories, [35], whose version 1.0 was released in April 2017).

We share the belief that it is both possible and desirable, to introduce computer aided visualization into such fields and graphically represent law, scientific theories, national economies, etc. What is more, we postulate the underlaying mechanisms and tools to be uniform and domain-agnostic: to represent any construct as a multidimensional entity composed of real and abstract dimensions, plus relations of real, temporal or mixed character. This way also cross-domain constructs could be represented and visualized. An example of such could be a legal contract: a document merging legal, financial, technical, temporal and possibly other aspects and whose visualization is both possible and desirable (as demonstrated, e.g. in [29]).

5. User interface with user-awareness

With traditional books the typical user awareness functions were accomplished with external devices: a bookmark keeping track of reader's progress, sticky marks pointing to important pages, highliters for marking key passages, pencil for making sidenotes. Naturally, the very same functionalities are now replicated in popular applications for document handling/editing, be it pdf, doc(x), odt, ePub, DjVu or other document formats. In addition, the text can automatically open on the page most recently read, user's viewing settings (zoom level, state of folding/unfolding of document elements, scrolling preferences, results of recently performed computations, etc.) are remembered and reused, links visited are shown with different color. It is already a considerable improvement with respect to paper, but with technologies available much more is possible.

An opening direction, the so called Rich User Experience (RUE), became possible due to new input and output technologies. It applies less to traditional desktop computer setup, where input is still carried out with keyboard and mouse, while for output the lion's share of information is presented visually with 2D screens (and the sonic channel plays and auxiliary role: generated-or-recorded speech, sounds and beeps, occasionally music). On the other hand, today's popular mobile devices make these two directions of man--machine interactions much more integrated and interwoven. The device's screen is both its main input and output where user's actions are not limited to typing or point-and-click but increasingly they are based on specific gestures and moves (e.g. two-finger swipe, shake). User's experience is further enhanced with haptic feedback, currently most often in the form of device's vibrations (e.g. confirming keystrokes) but prototype solutions purportedly provide also varying tactile sensation of friction or texture of touchscreen's surface (see e.g. [22]). The sonic communication channel is also increasingly often used both ways: generated speech as output and user's voice commands as input.

A number of other products have recently become mature enough to expand RUE even further, for instance with visual technologies providing 3D display capabilities, especially those going towards virtual (e.g. Samsung Gear VR) or augmented/mixed reality (e.g. Microsoft HoloLens) where computer generated 3D visualizations are rendered "into the world" on a see-trough, head-mounted display. Input part of the user interface has in turn been enriched with motion sensors (e.g. Microsoft Kinect detecting body movements), motion controllers (such as Sony PlayStation Move), or eye--tracking capabilities (e.g. HoloLens, again), and facial expression recognition (like person's smile triggering camera's shutter). Prospectively, this capabilities could even be applied to reading involuntary body signals – extended recognition of facial expressions could recognize surprise or joy while other biosensors (blood pressure, pulse, respiration, skin conductivity) integrated within touchpad could feed data to algorithms evaluating person's mental and emotional state (e.g. of tiredness or confusion, in a similar way as it was first implemented in a polygraph, a.k.a. "lie detector").

An important thread to mention in this context is the use of input and output technologies by persons with substantial visual impairments. Today, their lion's share of perceiving content is through speech generation, which poses serious limits. The use of haptic and tactile stimulants could change that dramatically. An interactive glove (see e.g. CyberGlove with CyberTouch, [21]) is capable of providing the sense of spatial objects virtually hovering in actual 3D space, with different (perceived) textures, shapes or weights. This capability could finally be used to engage such users' spatial imagination to grasp complex relationships among (real of abstract) entities.

All of the above novelties extending Rich User Experience can be leveraged to achieve the <u>most efficient document-to-mind transfer of information</u>. An important aspect of that is in adapting the mode of presentation to the user's wants and needs, disclosed either verbosely or involuntarily. Consequently, (re)presentation of the same "piece of knowledge" should be adjusted to the user's level (novice, moderate, expert), his particular need at hand (e.g. general browsing vs searching for specific details) and numerous other preferences or factors. For instance, a human anatomy content should present itself differently to a student starting the class and differently to (even the same) one reviewing the topic at the end of semester, just before his final exam. This clearly means that presentation should dynamically evolve together with user's progress – closely tracked and assessed. End-of-chapter self-assessment quizzes are one way to achieve this end but the abovementioned methods of interpreting involuntary inputs showing one's emotional state, would become increasingly practical. "Ultimately what we presumably want is an accurate computational model of every student. (…) Given this model what we'd then presumably do is in effect to run lots of simulations of what would happen if the student were told this or that, trying to determine what the optimal thing to explain, or optimal exercise to give, would be at any given time." [10].

6. Conclusions

Paper-centered mindset, still predominant in imparting information and knowledge, can be characterized by focusing on the use of textual description occasionally augmented with flat graphical illustrations. Its ongoing domination may seem to be a matter of inertia, as current trends indicate an increasing importance of alternative ways breaking up with that traditional path of sharing knowledge. Next to traditional, journal papers, there are now numerous other forms of scientific and technical communications leaning towards open access, multimedia and interactive content, digital data, collaborative authoring etc.

This trend is fostered by growing abundance of standards and computer tools for graphical modeling and presentation of knowledge. Available capabilities entail creating, presenting, storing, editing and distributing "knowledge containers" conveying content of vastly different kinds. Especially impressive is the level of maturity of applications dealing with modeling physical, real-world objects, roughly divided into GIS and CAD (/3D-modeling) categories. Methods and standards for representing abstract entities seem to be lagging behind – mathematical modeling, software engineering, system analysis or business process modeling still mostly use flat, static diagrams based on simple geometries and textual labels (although there are numerous proposals to expand into 3D). Still, they show that, at least in principle, it is possible to use graphical tools to represent structure of arbitrarily complex abstract entities. If so, it becomes likely to see, in near future, similar methods applied in other areas: law and legislature, political science, philosophy, etc. today still dominated by text.

These capabilities for interactive, graphical representation of knowledge may be further enhanced by applying novel user interface technologies of 3D displays (also for virtual and mixed reality), haptic feedback, motion sensors, eye tracking or facial expression recognition. Such Rich User Experience capabilities could provide more "intimate interaction" between the user and the content, to the point where not only the user understands the document but also document may understand and adapt to (the needs of) the user. Considering all that, these technologies enable us to make transfer of knowledge more efficient, i.e. requiring less time and effort to master it, as the content will be presented in ways easier to grasp with (spatial) imagination, more interesting and enjoyable.

In some areas we are actually very close to achieving that goal, one example being 3D interactive, animated anatomy atlas rendered in augmented reality (with Microsoft HoloLens, as presented e.g. on [23]). However, dealing with more abstract and general information of many fields still requires us to operate on text. It is, for instance, possible to use the same HoloLens to work on a legal agreement, but the whole use of augmented reality would in that case reduce to rendering "into the world" a flat screen with plain old text editor on it. The example shows that the tools and technologies are ready to display interactive, multidimensional, layered, time-varying, aspect-oriented content in a comprehensive way. What we are lacking is ideas (notations, standards) enabling us to apply the same principles and technologies to modeling and presentation of abstract, complex structures – such as a scientific theory, national economy, legal construct, etc.

We believe, that it is possible, and increasingly important to overcome this obstacle. In principle, any entity, real-world or abstract, could be viewed as residing in multidimensional space composed of physical, temporal and abstract dimensions. Its composing elements would then similarly be interconnected relationships of spatial of logical character. Once we design adequate graphical representations to "tame" the abstract dimensions and relations, we should be able to model and display any complex construct within three-dimensional, interactive canvas. That way our spatial imagination would become fully engaged in understanding – making for more effective learning. And that is what the idea of Spread Page is about. Naturally, projection of such content onto static 2D cellulose-based sheets would still be possible… but increasingly pointless.

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Fundamenty Spread Page: przegląd aktualnych koncepcji, rozwiązań, technologii pozwalających poprawić efektywność przekazywania wiedzy

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Proponowana przez autorów nazwa Spread Page odnosi się do nowego, bardziej wydajnego sposobu przekazywania wiedzy z dziedzin technicznych i naukowych, zrywającego z tradycyjnym podejściem „papierowym" i zorientowanego na reprezentację graficzną, interaktywną i wielowymiarową. Tematem artykułu jest przegląd współczesnych pomysłów i istniejących rozwiązań, które mogłyby znaleźć zastosowanie przy urzeczywistnianiu idei Spread Page. Dyskusja rozpoczyna się od omówienia nowinek organizacyjnych i formalnoprawnych dotyczących procesu tworzenia i rozpowszechniania wiedzy naukowej, zrywających z tradycyjnym modelem opartym na (papierowych) publikacjach. Następnie przedstawione zostały główne, używane obecnie, metody i konwencje graficznego modelowania obiektów rzeczywistych i abstrakcyjnych, razem z przykładami istniejących technologii i pakietów oprogramowania implementujących funkcjonalności pożądane z punktu widzenia proponowanej idei. Przegląd ten wykazuje, iż w pewnym zakresie tematycznym (dotyczącym obiektów realnego, trójwymiarowego świata – tj. np. w mechanice, topografii, anatomii) pożądane, „Spread-Page-owe" podejście do reprezentacji i przekazywania wiedzy jest już dziś w naszym zasięgu. Niestety w przypadku dziedzin bardziej abstrakcyjnych, takich jak prawo (i prawodawstwo), nauki polityczne czy społeczne itp., sytuacja jest odmienna, czego główną przyczyną jest brak adekwatnych notacji graficznych. Niniejszy artykuł jest jedną z kilku przygotowanych przez autorów wspólnych prac dotyczących idei Spread Page i dla pełniejszego zrozumienia postulowanego pomysłu warto zapoznać się także z pozostałymi.

Słowa kluczowe: graficzna reprezentacja wiedzy, Spread Page.