Towards a Marketplace of Visual Elements for Notation Design

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***Abstract*— New visual languages and extensions of existing notations are increasingly introduced for various purposes. There are many frameworks and theories that aid designers in creating cognitively effective visual notations. They usually provide general guidelines, which are not easily operationalized without extensive user involvement. However, often such user involvement is difficult to achieve, especially in scientific settings where finding enough participants with the needed background knowledge is far from trivial. In this paper we propose the idea of creating a searchable marketplace of visual elements, in which designers could share and exchange elements of visual notations. A key feature of such marketplace would be the ability to certify such elements via procedures grounded in empirical research. We discuss a proposed structure of the marketplace, and the challenge that the need for certification poses to its design.**

***Keywords*— cognitive effectiveness, visual notations, modeling languages, user involvement, crowdsourcing.**

I. Introduction

Conceptual modeling is a widely used technique in information systems development to describe a specific domain as understood by its stakeholders [16]. Conceptual models are used extensively for understanding and communicating about requirements of e.g., an information system, software or some other intended artifact [17]. There is a large number of modeling languages for many specialized purposes, most of which have their own visual notation. It is important that such visual notations are cognitively effective (i.e., that the notation can be effectively and correctly understood by its intended users) in order to facilitate communication during the modeling process.

Accordingly, research into the cognitive effectiveness of notations has seen a strong growth in recent years, and many frameworks and theories have been proposed to aid designers in creating more cognitively effective notations (e.g., [14, 1, 2, 3]). However, these usually come in the form of general guidelines, and exactly how to implement them is left to the free interpretation (or preferences) of particular designers. Moreover, as discussed in [4], the operationalization of some of the principles of these frameworks, in particular those of the Physics of Notations, requires end-user involvement, which is usually a task requiring experimental setups that are not easily arranged, perhaps a reason why user involvement is typically low [5]. Finally, there is no systematic way to establish collaboration between different designers: many times they end up reinventing the wheel, coming up with variations of already existing visual notations for the same – or even worse – completely different semantic constructs, a pitfall to be avoided [1].

What if designers of visual notations had a collaborative platform for coordinating their efforts? While the coordination of the design of entire visual notations seems difficult, one could start by setting up an open library of visual elements that could serve as building blocks for visual notations and their extensions. Such library would be a kind of a *marketplace*, where visual elements and their corresponding semantic constructs could be shared, exchanged, rated, discussed – and ideally, certified via well-designed user involvement. Certified here means that a visual element has been found to be well designed and validated for its intended modeling purpose, based on an accumulation of results according to rigorous empirical evaluation procedures, such as e.g., experiments showing the effect of representation size on cognitive load [20]. The idea of a community creating a shared marketplace of certified artifacts is not new: like in the field of viruses and anti-viruses, which is very cooperative today, such initiative was recently introduced in Dale Miller's ProofCert project [15], where a marketplace of proof systems is being created, aiming to standardize and certify proof systems, index them in a library and make them available for wider use. Another example of collaborative efforts is open source repositories such as SourceForge, which allow developers to search for existing implementations of an application or algorithm, having access also to user feedback and rating, as well as descriptions of bugs and problems.

In this paper we present our vision for a marketplace of visual elements, a place for sharing, exchange and validation of visual resources, getting inspiration, feedback and help. Its content would be easily searchable and structured in a way helpful for (re)designing notations, as a complementary tool to theoretical frameworks, such as the Physics of Notations [1], as well as for research and education in this field.

The rest of this paper is structured as follows. Section II provides some motivation for viewing visual elements of visual notations as "marketplace goods" and discusses some scenarios in which these goods could be shopped for (or searched). Section III provides an overview of the requirements for the envisioned marketplace and its needed functionality. Section IV discusses some particular challenges that arise from these requirements. Sections V and VI discuss the impact, benefits and other topics for future work that require research attention. Section VII summarizes and concludes.

II. The What: Visual Elements

The "goods" of our marketplace are visual elements, which are used as building blocks of visual notations. Following the view taken in [4], by a visual element we mean a graphical element which has an attributed meaning (or semantic construct), as well as a symbolic meaning (e.g., connotations the element raises in someone), and is represented by visual variables (such as shape, color, texture, etc.). For example,  , is a visual element of BPMN which is used for the concept of a message. Its specified semantics is: "A **Message** represents the content of a communication between two *Participants*." The visual element itself though, may carry additional symbolic meaning depending on what connotations the person viewing it has (e.g., "an information carrier", "a private thing"). It is represented by a number of visual variables, in this case of a rectangle consisting only of black lines and no texture filling.

Coming to a marketplace, one may search for specific items (strawberries), or more abstract items (red seasonal fruits). In a marketplace of visual elements, any attribute of the elements (semantic/symbolic meaning, visual parameters), as well as other characteristics can be used as search keys. In what follows we discuss the motivation for different types of search keys using examples[1] of visual elements used in BPMN extensions, and what requirements they might pose towards a marketplace where people can collaborate on their design.

A. Symbolic vs. Semantic Meaning: Searching for Bolts

Sometimes the same graphical symbol is used in different notations (or different dialects thereof) to represent different semantic constructs. Conversely, the same (or closely related) semantic construct can be represented using different symbols.

For example, there are several BPMN extensions that use the symbol of a lightning bolt to represent a specific meaning, varying from e.g., "an agent always having the capability to execute a task" to "a workaround for a task" [6,7,8]. This is potentially confusing to users of both extensions, and may also lead to a particularly dominant extension setting the *de facto* meaning of lightning bolts in process models. In a marketplace where the lightning bolt were shown with all possible semantic meanings explained, users could provide feedback, and perhaps vote on what meaning comes most clearly to them, in some particular context. This would provide valuable insight to the designers of such notations, not only by seeing how other designers have used lightning bolts, but also what the preferred interpretation of users in particular contexts is.

Another example of a visual element with multiple meanings is a magnifying glass. One particular extension to BPMN [9] uses this visual element to represent elements that are "auditable". This is a strongly domain-specific meaning, using a more general symbol, which often has other semantics associated with it. In this case, one could expect that many users would wrongly infer that the magnifying glass would represent elements that should be "searched for", or "require details", and so on. This could take the form of user feedback in our envisioned marketplace.

Similarly, there can be cases in which identical, or very closely related, semantic constructs are visualized by distinct symbols. For example, there are many security and access control extensions of BPMN, all of which share some common semantic constructs, for example *non-repudiation*. This same construct is represented by different extensions as either e.g., a lock [19], or a symbol of a crossed out arrow in a circle [18]. The marketplace here could add value for designers in becoming aware of this duplications, as well as of what symbol is the best choice for a particular meaning in a given context. By incorporating explicit evaluation procedures for e.g., how well a symbol suggests its meaning, a wealth of comparative data could be made available for designers for ensuring that their visual notation fits with the way their users think.

B. Visual Parameters: Searching for Red Items

Different combinations of visual parameters are commonly used to represent particular semantics. For instance, there is a large number of BPMN extensions which use color to annotate a particular meaning to elements. Thus, a particular task in a process model can be colored red to represent that it is a risk to something else. Few people would disagree on the intuitiveness of the use of such visual elements, although red-green color-blind people might object to it if it were used together with conflicting colors. However, when the same visual element is also used for different meanings, for example to signify high cost of a particular task in a process [10], it again becomes more difficult to make sense of all the different uses of the same visual element. The marketplace here could again offer value to both designers and users by showing how fragmented the user of a particular visual element already is, what it is used for most often, and more. For example, if a designer sees that red coloring of elements is used in dozens of different ways, with most users indicating that they really prefer it to be used for "dangerous" or "risky" things, that designer would likely reconsider her thought to use red coloring to indicate "urgency" or the like, regardless of whether users could easily *learn* those specific semantics [11]. Furthermore, users would also be able to vote on design considerations of color combinations, and so provide valuable feedback to notation designers. For example, a symbol of a crossed out arrow placed in a circle could be unproblematic in itself, but when it is specifically expressed as a black arrow, crossed out by a red line, placed on an orange background [18], users might be more critical of its readability.

C. Drawability & Readability: Searching for Simple Elements

Simplicity in graphical design is of essence when it comes to ensuring the *drawability* and *readability* of visual elements, let alone models composed of many of those individual elements interacting. In particular, when conceptual modeling is done *offline,* without the use of computer tools, it is important to be able to draw the relevant symbols. Furthermore, even if one is using software to draw and read models, it is important

[1] These examples were obtained as part of our ongoing research effort focused on analysing the cognitive fit of visual notations with their users (cf. [4,5] on challenges of user involvement and operationalization). We are building a classified dataset of the additions and modifications that extensions make to the core BPMN visual notation. Given the high number of BPMN extensions, this provides ample exercise to analyse the landscape of design choices made by visual notation designers in a particular context.

that the symbols remain readable and distinguishable at different levels of *zoom*. For example, a BPMN extension dealing with wireless sensor networks [12] introduced some symbols essentially consisting of multiple smaller symbols, that are difficult to draw and read. When such visual elements are used in a larger context, it becomes especially clear that a symbol might be too complicated for its own good, as shown in Fig. 1.

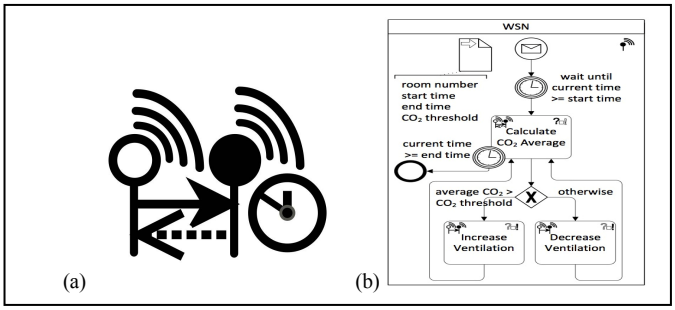

Figure 1. Example from [12] of a visual element (a) that is difficult to draw by hand, and likely difficult to read in even simple model contexts (b).

From this example it becomes clear that some properties of visual elements are not as straightforward to capture as others. While it is trivial to capture whether a visual element is red or blue, a rectangle or a circle, or what its specified semantics is, whether it is readable and drawable requires something more. One of the crucial features of our envisioned marketplace is the ability to evaluate visual elements according to verified validation procedures, leading to certified visual elements, in this case whether symbols are too difficult for users to draw or read in particular contexts.

III. The Where: a Marketplace of Visual Elements

The previous section provided some motivation for exchanging and sharing visual elements as marketplace goods. Here, we explore in more detail the envisioned form and function of the marketplace itself.

A. The Marketplace

The marketplace is essentially a front-end for a database of annotated visual elements used in visual notations. Its content is user-generated. As such, its interface takes the form of a search form where users can look for specific notation elements, or any combination of visual parameters that a visual element might satisfy. Say a user wishes to search for a symbolic visual element, with the shape of a lightning bolt, and of a blue color. This query would then return any matching visual element, its source, meaning and other relevant information contained in the database. This example is depicted in Fig. 2.

B. Users

The marketplace will be driven by its users, as the majority of its content will be user-generated. While for an initial launch the database can, and likely will, be pre-filled with data on existing visual notations, the users of the marketplace will be the predominant stakeholders that both add and derive value from its content. For the sake of simplicity, we do not make a distinction here between users adding content as designers of notations, and users who are modelers 'merely' using a notation.

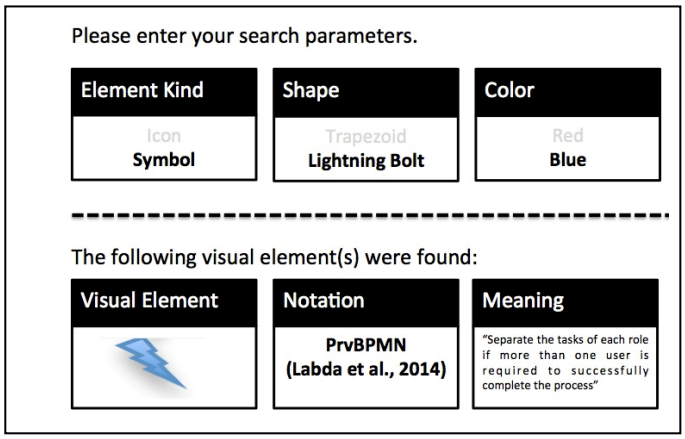

Figure 2. An example of a search for a particular combination of visual variables in the marketplace and its results.

C. Features

The marketplace would have a number of core interactions, as described below:

Search for visual elements

As demonstrated in Fig. 2., the marketplace users can search for visual elements already in the database. Such searches can be done to look for how elements are used, to gain inspiration for a new notation, or to better tailor one to notation users preferences. The search for a visual element can be done by its properties as discussed in Section II, as well as additional useful properties such as a corresponding notation (e.g., GRL, BPMN, UML, extension of existing notation), modeling context (e.g., processes, goals, architecture), or domain of use (e.g., government, healthcare, telecom, software engineering).

Add new visual elements

The marketplace users can add a visual element that is not yet available in the marketplace. To do so, they will need to enter typical properties including name, description, used source, relevant visual variables, and so on. Most importantly, they need to provide a *means of evaluation* of the visual element itself, by which they have already, or intend to, verify that the visual element is cognitively effective. Other users can access this information about the means of evaluation, its results, and by so doing also judge how *trusted* the design of that particular visual element is.

Add evaluation procedure

When a new visual element is added, the designers of this element are strongly encouraged to immediately add the evaluation procedure that they used to ground its design in existing literature, experimental protocol or empirical data. This evaluation procedure is fundamental to the marketplace, as other users can replicate or otherwise verify the evaluation in order to review the elements and further contribute (or detract from) its *trusted* nature as a well-designed visual element.

Add data to existing visual elements

Users can add additional or missing data to visual elements. For example, if some visual elements were added without their particular meaning in the notation, someone can add the exact semantics. Users can also add data to a visual element if it differs in a particular modeling context or domain. This is distinct from reviewing the element, as this has to be done according to the established evaluation procedure.

Review existing visual elements

Reviewing existing visual elements is done according to the evaluation procedure provided by either its original contributor, or another user who added an evaluation procedure. Evaluation procedures are required to be grounded in empirical evidence, and show clear replicable steps to achieve a justification for the visual element being well designed. Marketplace users can perform these evaluations and accordingly rate whether to add to the visual element's certification, or detract from it, i.e., if they were not able to replicate the positive results claimed by the element designer or other users.

The functionality described here is summarized in a Use Case Diagram shown in Fig 3. below.

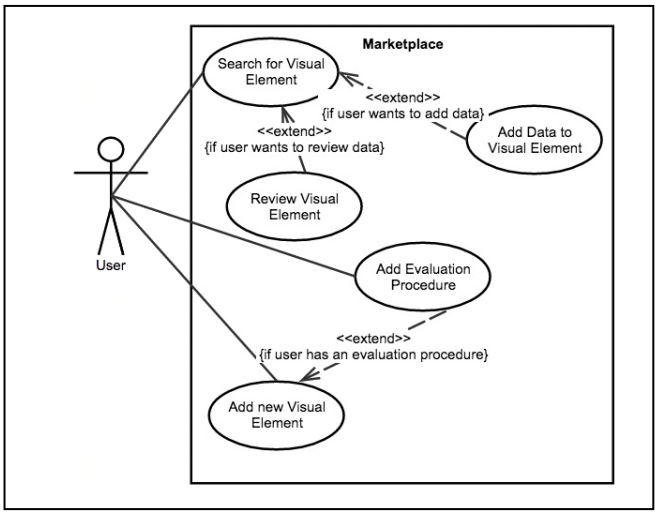

Figure 3. Use Case Diagram of the Marketplace functionality.

IV. The How: Reviewing Visual Elements

The most important aspect of the marketplace is the reliability of its content. Its first and foremost challenge is thus to ensure that the content is not prone to arbitrary judgments, e.g., "*I just don't like using a lightning bolt symbol*." As a result, the successful implementation of the "**Review existing visual elements"** functionality is thus the most vital to the success of the proposed marketplace. This has two reasons:

1. The data gained by users reviewing the understandability of visual elements, especially in particular contexts or domains, is the most valuable data as it is not often elicited or available during the design of visual notations.
2. The procedure for reviewing visual elements has to be grounded in thorough evaluation procedures, so that their outcomes lead to increased trust of the visual elements.

The evaluation of visual elements in the marketplace would, depending on the visual element itself, have to be done on different aspects. Based on the aspects we have discussed in Section II, we can identify a number of evaluation procedures, which would be challenging to design. As the marketplace is filled with additional visual elements, other challenges might arise, for which continued attention into well-specified evaluation procedures remains important.

A. Assessing Symbolic Meaning vs. Semantics

Assessing whether a particular symbol suggests its meaning, in line with the Physic of Notations' *semantic transparency* principle, is particularly difficult to operationalize, especially because it requires user involvement to validate what a visual element means to someone [4]. Part of the difficulty of operationalizing it is that the meaning someone takes from a particular symbol can vary wildly from person to person, as well as from context to context. Thus, simply asking people whether a given visual element is a good fit with a given meaning is not likely to lead to much certainty.

Perhaps such procedures should instead attempt to reduce the complexity of this matter as much as possible by reducing the context, so that the total range of potential meanings becomes more manageable. For example, to review whether a particular visual element represents its meaning well for the intended context, first a context-free questionnaire could be distributed, where the visual symbol is first shown by itself, after which the user is asked to assess its meaning. These results can be compared to the given meaning associated to the visual element. Following this, the visual element could be shown in a realistic context (i.e., as part of an actual model), again asking the user to assess its meaning. Then, the results could again be compared to the given meaning. Over time, the elicited answers from users on what a symbol means to them could be used to generate clusters of meaning, as the results will likely start to converge.

It should be noted that these considerations apply to those visual elements that were designed to express a meaning related to their appearance. On the contrary, some visual elements are indeed meant to be void of connotations [1], such as for example the use of rectangles to denote tasks in BPMN. The link between such visual elements and their meanings is not meant to be intuitive, but can be learned easily [11], and is also less likely to lead to situations where users are confused because they would infer a different meaning [1], e.g., "I always thought rectangles were resources."

B. Assessing Visual Parameters

Assessing whether the visual parameters of a given element are appropriate or could use refinement deals more with perceptual rather than cognitive aspects, requiring different procedures grounded in empirical data. For example, when it comes to color use, there is ample data showing us what color combinations are difficult to read, what combinations would be particularly difficult for some people, such as the color blind. Nonetheless, there can be many cultural and personal specific differences in what connotations users have of particular colors, or combinations, which make it important to tailor color

use to particular contexts of use. A potential evaluation procedure could for example take the form of presenting the visual element being presented in different color combinations, where users have to assess the most readable form, and be further operationalized by requiring users to 'read' a visual element and give its textual equivalent, similar to CAPTCHA tests.

C. Assessing Readability & Drawability

Assessing whether something is readable seems intuitive and simple to most users, but ensuring scientifically valid assessment requiring systematic and replicable procedures is more complicated. For example, many people would immediately question the readability of the complicated symbol shown in Fig. 1. However, if we want to ask specific questions in order to determine whether it is readable, how would we do so? One option would be to ask whether the symbol consists of multiple smaller symbols, if it requires a particular number of strokes to draw, if its parsing leads to a high cognitive load and so on, all of which require grounding in literature and empirical evidence, which may not be easy to come by. Moreover, evaluating the drawability of a visual element is no less complicated. One could attempt to count the number of strokes necessary to draw a particular symbol. However, without grounding such operational decisions in empirical evidence of e.g., how many strokes are too many, such operationalization runs the danger of being based on arbitrary choices [4].

V. Benefits and Impact of the Marketplace

A. Increase Collaboration on, and Reuse of, Visual Elements

Keeping up-to-date with other's efforts of designing visual notations is a non-trivial task for notation designers, as the description and specification of visual elements for a given notation is often fragmented over numerous scientific publications, and not easily searchable. The envisioned marketplace aims to provide a collaborative platform, supporting a searchable library of trustable artifacts for their exchange, sharing, feedback and inspiration. Some of the challenges discussed in Section III such as homonymous symbols, confusing color and other pitfalls could easily have been avoided in the presence of such marketplace.

It should be noted that the marketplace does not replace or compete with other theories that researchers might wish to use to improve the cognitive effectiveness of their visual notations (such as, e.g., the Physics of Notations or Cognitive Dimensions), but can be a valuable complementary resource to strengthen their application of such theories by providing insights specific to users of some notation.

B. Coordinate Efforts of Certification of Visual Elements

The marketplace can offer additional value to designers of languages and analysts in certifying user-related features of visual elements such as understandability, distinguishability, and readability and drawability. This is especially valuable when creating a dialect for a specialized domain, as the marketplace can offer insights into context-specific use of visual elements, and thus show what elements, used in what context, might be best suited, or indeed, expected by notation users in that context. Given the general lack and difficulty of involving users in efforts of designing visual notations [5], the marketplace has the potential to be of aid by potentially reducing the need for notation user involvement during design by its collection of certified elements for specific tasks and contexts.

C. Add Value Towards Research & Education Efforts

The marketplace and its content can become a significant source of value for research and education efforts as it grows in size and scope. Researchers would have the benefit of having access to a well structured database that lends itself for comparative works, e.g., do modelers in task *x* have different preferences than modelers in task *y*? Does the design of notation *z* fit with what its intended users want/need?). Educators can use the content to teach students or professionals about the way visual notations are used in actual practice. Furthermore, researchers analyzing the cognitive effectiveness of existing visual notations would be able to further assess user-related aspects with insights found in the marketplace's reviews.

VI. Discussion

A. How Would the Marketplace Get Initial Momentum?

The challenge of user involvement also applies to ensuring the marketplace generates enough content. It is important to ensure that users can generate valuable content from the start, by reviewing existing visual elements. In order to do so, we propose to populate the marketplace from its inception with data covering the visual elements of highly used modeling languages (e.g., BPMN, i*, UML, ArchiMate). In particular, it is important to provide procedures for reviewing the visual elements so that users can review elements from the beginning, thus immediately leading to more insights into user-specific interpretation and trust of the visual elements. We would use current insights and data from our ongoing research program into the cognitive fit of modeling languages to their users, in order to seed the marketplace, in particular focusing on visual elements from popular modeling languages where notation users to involve in certification is most feasible.

Given the availability of these data from the start, the threshold for marketplace users to review existing elements is set low, so that their involvement will be more likely, and their contributions would require less commitment, compared to what would be required from e.g., adding new visual elements and review procedures, or amending data on existing visual elements for other contexts of use.

B. Would the Marketplace Lead to Overly Similar Notations?

A concern of a marketplace in which its users review and work towards their preferred visual elements is that eventually everything will start to look the same. If users keep certifying that a golden symbol of a lock with an exclamation mark emblazed on it (to name one example) is the most intuitive symbolic representation for a concept like *valuable content,* one could expect most designers to pick up on it and use it in their visual notations. In essence, visual notations would start converging, especially if they deal with similar domains, as more

and more preferred visual elements for particular semantic constructs become clear.

However, this does not have to lead to any negative concerns. Cross-language readability would likely increase, with users more likely to intuitively understand the meaning of other modeling languages with which they were not yet familiar. When the meaning of a particular entity in a model has to be specialized to that notation or domain's focus, instead of adopting different symbolic representations, a textual annotation nudging the user into the exact interpretation of the visual element could be added.

If the experiments with suggestion of meaning in essence reduce the total number of symbols used because 'ideal' symbols become locked for particular meanings, that would only increase cross-language readability and understandability. This is not a negative point for a visual notation itself, as specialization of the semantics induced by the visual aspects can be provided by dually encoding meaning with textual annotation (cf. Moody's explanation of dual coding principle).

C. Is it too Focused on 'Atomic' Visual Elements?

The marketplace, as we have presented it, focuses on individual visual elements. This takes them out of their natural context of an actual model, which further impacts the overall cognitive effectiveness. For example, even if all individual visual elements are certified by the marketplace to be well designed, the way in which they come together might still emergently lead to unforeseen negative design considerations. However, being able to certify and trust the individual visual elements is a necessary first step towards being able to deal with the more complicated situation of models composed of many interacting elements. The investigation of the cognitive effectiveness of models as 'atomic' artifacts themselves is thus out of the scope of this marketplace and our work.

VII. Conclusion

In this paper we have argued for the creation of a marketplace to inform the design of visual notations for conceptual modeling languages, in particular on aspects that require explicit user involvement. We described several open challenges that can be found in the design of contemporary visual notations (and extensions thereof), and provided an outline of the different kinds of peer-review experiments that can drive a catalog of solutions there. The most natural next step will be to propose a concrete structure for the marketplace, including all relevant information that should be included for a visual element, and its representation. In future work we also aim to implement an online collaborative working environment, likely based on Wiki technology, in which the proposed ideas will be implemented.

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