

# Inspecting Visual Notations for UsiXML Abstract User Interface and Task Models

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## ABSTRACT

In this paper, we analyze the current state of visual notations in UsiXML models for Abstract User Interface and Tasks model. A systematic analysis is presented according to Visual Variables framework – a widely considered work in graphic design field. Some directions on evolution of the visual notations are also presented.

## Author Keywords

Measurement, Design, Human Factors, Standardization, Theory.

## General Terms

Design, Human Factors, Theory

## Categories and Subject Descriptors

D2.2 [Software Engineering]: Design Tools and Techniques – *Modules and interfaces; user interfaces*. D2.m [Software Engineering]: Miscellaneous – *Rapid Prototyping; reusable software*. H.1.2 [Information Systems]: Models and Principles – *User/Machine Systems*. H5.2 [Information interfaces and presentation]: User Interfaces – *Prototyping; user-centered design; user interface management systems (UIMS)*.

## INTRODUCTION

Diagrams have the power of expressing ideas in a very effective way, because we are able to summarize concepts inside an image that would take pages to explain in textual form – textual representations are one-dimensional (linear), while visual representations are two-dimensional (spatial) [7]. Also, expressing ideas in visual and spatial medium makes comprehension and inference easier, since a quarter of the human brain is devoted to vision, which is a bigger percentage than all other senses combined [6].

It is not an easy task to design visual notations, in part due to the lack of scientific methodologies available to analyze them and to make conclusions regarding what makes a good diagram. Yet, diagrams play a critical role in all areas inside software development from requirements engineering through to maintenance.

Although the Software Engineering community has succeeded to develop methods to evaluate and design model's semantics, the same is not true to models visual syntax.

This work's aim is to do an inspection of currently available visual notations of UsiXML, mainly focusing on Abstract User Interface and Tasks models (and not yet for Concrete User Interface, Domain and Context models). The two chosen models for this analysis are more central to UsiXML than the others, and therefore are where an analysis such as the one presented on this work is expected to have more value. The driving question of the inspection is: *Are all the elements and relations of the meta-model represented on the visual notations?* We try to address it in terms of **how** to represent what is missing. Thus, this work does not intent to define what the meta-models should represent, but only whether the visual notation comprises to what is stated on the meta-model.

The next section first presents some definitions of visual notations in the domain of Software Engineering (SE), and then we present the Visual Variables framework and the conceptual basis for the analysis. The section 3 presents the analysis itself along with some recommendations of use for each variable. We conclude with some preliminary work on graphical editors, which are along with evidences that they comprise with the recommendations.

## STATE OF THE ART

In order to describe what visual notations are, some basic concepts need to be presented. The first and most basic is that diagrams are encoded as two-dimensional geometric symbolic representation of information, and this information refers to something that is outside of the diagram itself.

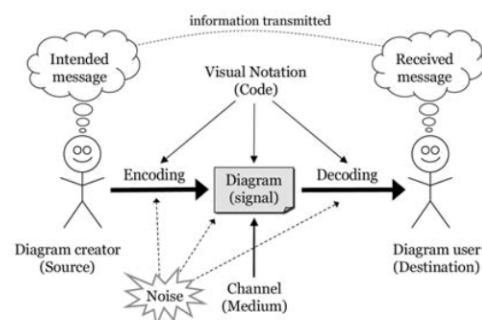


Figure 1. Theory of diagrammatic communication.  
(Source: [11]).

In general, the communication process using diagrams can be described as in Figure 1: a diagram creator (the sender) encodes information (message) in the form of a diagram (signal) and the diagram user (receiver) decodes this signal. The diagram is encoded using a visual notation (code), which defines a set of conventions that both sender and receiver understand. The medium (channel) is the physical form in which the diagram is presented (e.g., paper, white-board, and computer screen). Noise represents random variation in which the signal can interfere with communication.

The match between the **intended** and **received** messages defines the effectiveness of communication. In this sense, communication consists of two complementary processes: encoding (expression) and decoding (interpretation).

As pointed out by [11], in order to optimize communication both sides need to be considered: of the encoding: *What are the available options for encoding information in visual form?* This defines the **design space**: the set of possible graphic encodings for a given message; and of the decoding: *How are visual notations processed by the human mind?* This defines the **solution space**: principles of human information processing provide the basis for choosing among the infinite possibilities in the design space.

### Design Space

For the design space, we can account for the visual variables defined by Semiology of Graphics [1], a widely considered work in graphic design field. Like showed in Figure 2, it defines a set of atomic building blocks that can be used to construct any visual representation in the same way the periodic table can be used to construct any chemical compound.

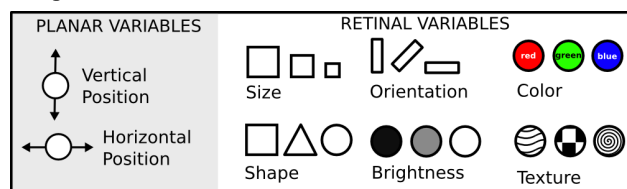


Figure 2. Visual variables.

The visual variables thus define the dimensions of the graphic design space. The visual variables also define set of primitives (a visual alphabet) for constructing visual notations: Graphical symbols can be constructed by specifying particular values for visual variables (e.g., shape = rectangle, color = green). Notation designers can create an unlimited number of graphical symbols by combining the variables together in different ways.

### Solution Space

For the solution space, we take into consideration that humans can be viewed as information processing systems [NS92], so designing cognitively effective visual notations can be seen as a problem of optimization of this processing (Figure 3).

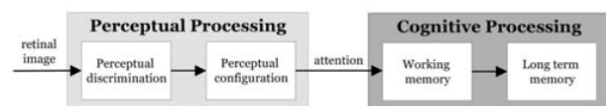


Figure 3. Information processing by the human mind. (Source: [11]).

The more evident benefit of using diagrams is perhaps the **computational offloading**, which is the shift of the processing burden from the cognitive system to the perceptual system, which is faster and frees up the scarce cognitive resources for other tasks.

The stages in human graphical processing are:

*Perceptual discrimination*: Features of the retinal image (color, shape, etc.) are detected by specialized feature detectors and based on this, the diagram is parsed into its constituent elements, separating them from the background (figure-ground segregation) [13].

*Perceptual configuration*: Structure and relationships among diagram elements are inferred based on their visual characteristics [13]. Winn had made a study to investigate

*Attention management*: All or part of the perceptually processed image is brought into working memory under conscious control of attention. Perceptual precedence determines the order in which elements are attended to [13].

*Working memory*: This is a temporary storage area used for active processing, which reflects the current focus of attention. It has very limited capacity and duration and is a known bottleneck in visual information processing [4].

*Long-term memory*: To be understood, information from the diagram must be integrated with prior knowledge stored in long-term memory. This is a permanent storage area that has unlimited capacity and duration but is relatively slow [6]. Differences in prior knowledge (expert-novice differences) greatly affect speed and accuracy of processing.

One could argue to use another frameworks such as Cognitive Dimensions [2]. However, despite of its wide use over time to evaluate all sorts of artefacts, there are several reasons for this framework does not provide a scientific basis for evaluating and designing **visual notations**. As pointed out by [11]:

- It is not specifically focused on visual notations and only applies to them as a special case (as a particular class of cognitive artefacts) [5].
- The dimensions are vaguely defined, often leading to confusion or misinterpretation in applying them [5].
- It excludes visual representation issues as it is based solely on structural properties.
- Its level of generality precludes specific predictions, meaning that it is unfalsifiable.

Physics of Notation covers the aforementioned shortcomings of Cognitive Dimensions. As it is a more theory-

grounded framework, it was the chosen one for evaluating UsiXML notations. However this paper focuses on the **design space** for its inspection, thus it begins with Visual Variables, as it is part of the Physics of Notations framework. For the **solution space** a broader analysis needs to be taken, this time based on the whole Physics of Notation framework.

### Visual Variables

The analysis uses the visual variables arranged around eight axis (one for each variable) in a way similar to Galactic Dimensions [3], but instead of comparing different languages on the same graphic, we are comparing different **versions** of the same language (current and future). Therefore, three steps are considered on each axis (Figure 4):

*Relevant / Good use*: the variable is relevant to the visual notation according to some concept on the meta-model. In other words, the concept of which the variable refers is clearly represented on the diagram.

*Ambiguous / Bad use*: the variable does not represent any concept of the meta-model but is present on the diagram, or the variable is used to represent more than one concept.

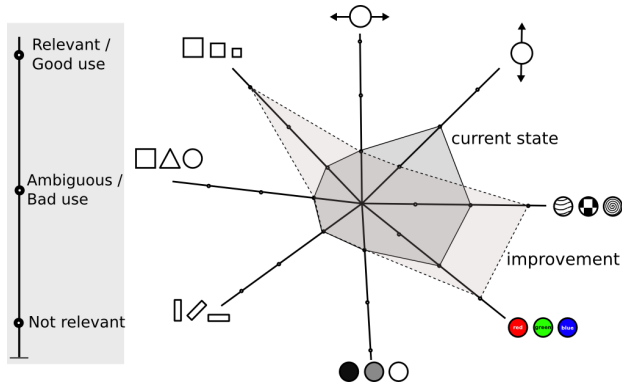


Figure 4. Visual variables and one example analysis.

*Not relevant*: If the variable is not present on the diagram thus not representing any element on the meta-model.

A visual variable can be relevant or irrelevant to the model (thus in a consistent state with the meta-model) but may never be ambiguous.

Two graphs are plotted over the axis: the darker and solid one represents the current state of the visual notation and the lighter and dotted one the improvements that can be made. For instance, if the Color variable is on the *Ambiguous* state, it is either changed to *Relevant* (the diagram can use Color to represent 'Object Type', for example) or *Not relevant* (Color should not be present, thus no suggestion is made regarding what concept to map using this variable).

### ANALYSIS

Having the frameworks presented before, this section will analyze the current state of the visual notations of UsiXML. This section, however, do not intent to define

what the meta-model should represent, but only if the visual notation comprises to what is stated on the meta-model.

Therefore, the fundamental question to be answered when evaluating the current state of UsiXML visual notations is: *Are all the elements and relations of the meta-model represented on the visual notations?* In other words, is the expressivity of the meta-model diminished or augmented onto its correspondent diagram?

This section will present the analysis of the following visual notations of the UsiXML models: Abstract, and Tasks. A visual notation can be inspected based on the visual variables that compose the design space.

### Abstract User Interface

The AUI model is an expression of the UI in terms of interaction spaces (or presentation units), independently of which interactors are available and even independently of the modality of interaction (graphical, vocal, haptic, etc) [8]. In this analysis we chose IdealXML's Abstract Model Editor [10] (Figure 5) as it is the most used visual notation for AUI, based on the high number of references on UsiXML related publications. Some other visual notations for AUI were proposed and it was based on already existing propositions (but not implemented).

An AUI defines interaction spaces by **grouping** AUIs (and implicitly tasks of the task model) according to various criteria (e.g., task model structural patterns, cognitive load analysis, semantic relationships identification).

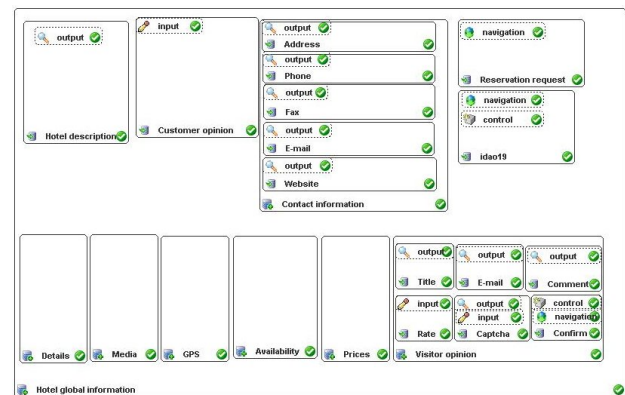


Figure 5. AUI model in IdealXML [10].

A set of abstract relationships is provided to organize AIOs in such a way that a derivation of navigation and layout is possible at the concrete level. An AUI is considered to be an abstraction of a CUI with respect to modality [8].

Based on these definitions, we can observe that the most important concepts are:

- *Grouping* – which AUIs contains other units
- *Hierarchy* – which AUIs have a higher level of importance
- *Ordering* – which AUIs have a higher level of precedence

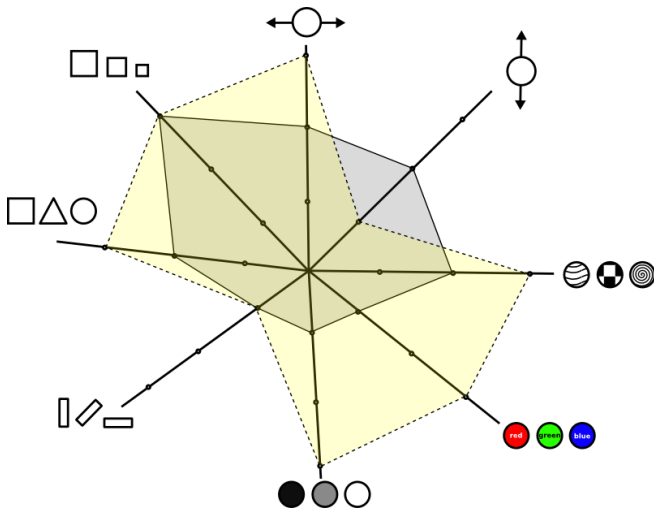
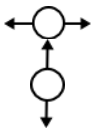
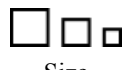
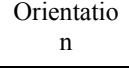


Figure 6. Abstract User Interface analysis.

| Dimension                                                                                       | Current state analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                 | Improvement proposition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <br>Position | <p>As previously observed, position should not matter for an abstract user interface model, since the human brain is capable of perceiving the slightest differences on this planar variable, positioning demands attention for irrelevant details, ultimately misleading the interpretation.</p> <p>Ex: In IdealXML the small accidental differences yields unintended meaning about element's positioning. (Those differences are marked with the symbol <math>\perp</math> on the figure below, for sake of visualization. The color is removed for the same purpose.)</p>  |
|                                                                                                 | <p>Fine positioning should not be considered in a visual notation that is intended to be independent of modality, for the bi-dimensional space does not exist on the abstract level. However, even though diagrams need to be represented on a bi-dimensional space, some care need to be taken in order to avoid the designer to make statements about the position of elements. One effective strategy to diminish its importance is to make the elements <b>aligned all the same</b>.</p>                                                                                                                                                                      |

|                                                                                                    |                                                                                                                                                                                                                               |
|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <br>Size          | Size is very relevant for representing <b>grouping</b> among the entities in the model.                                                                                                                                       |
|                                                                                                    | Size should indeed be relevant for representing grouping. However, in order to not give meaning to units with different heights or even to prevent the designer to worry about those details, they should have the same size. |
| <br>Shape         | Shape has a big relevance in the notation used by IdealXML, since the icons's shape at the side of the labels is the <b>only</b> indication of the functionality of a given abstract unit.                                    |
|                                                                                                    | However, there is an ubiquitous check icon (✓) that is not used to represent anything in the meta-model.                                                                                                                      |
| <br>Brightness    | Icons can be used as a complement, overloading the semantics yielded by other variables such as Color and Texture.                                                                                                            |
|                                                                                                    | This dimension is not used on the visual notation                                                                                                                                                                             |
| <br>Texture     | This dimension could be used to represent the <b>frequency</b> attribute, for instance.                                                                                                                                       |
|                                                                                                    | This dimension is not used on the visual notation                                                                                                                                                                             |
| <br>Color       | This dimension could be used instead/in complement of icons.                                                                                                                                                                  |
|                                                                                                    | This dimension is only used in the icons                                                                                                                                                                                      |
| <br>Orientation | This dimension could be used to represent the <b>importance</b> attribute, for instance.                                                                                                                                      |
|                                                                                                    | This dimension is not used on the visual notation                                                                                                                                                                             |
|                                                                                                    | No proposition                                                                                                                                                                                                                |

## Tasks

The Task model describes the interaction among tasks as viewed by the end user perspective with the system. A Task model represents a decomposition of tasks into sub-tasks linked by task relationships. In this analysis we chose CTT (ConcurrentTaskTrees) [12] (Figure 7) as it is the most used visual notation for Task modeling, based on the high number of references on UsiXML related publications.

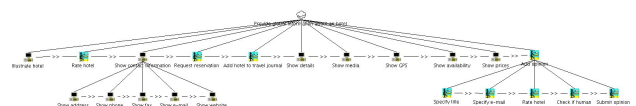


Figure 7. ConcurrentTaskTrees model.



Is important to note that in CTT (and in largely all task models) what is represented in its hierarchical diagram is not importance, but composition or **structure**. Furthermore, in CTT the sub-tasks are always related to each other through operators, which represents **behavior** as well.

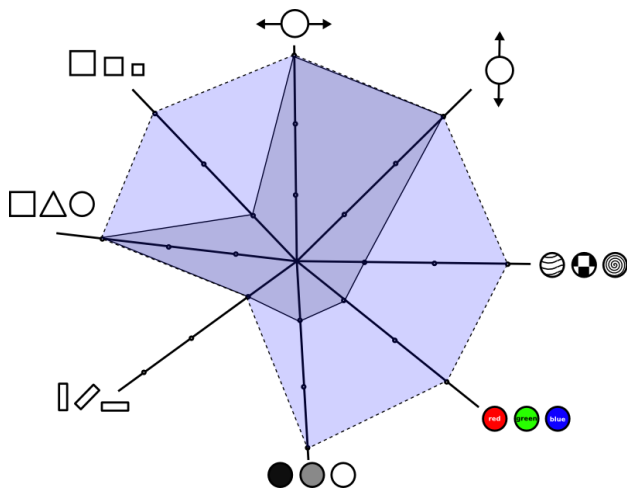
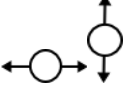
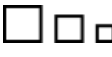
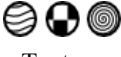


Figure 8. Tasks model analysis.

| Dimension                                                                                       | Current state analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                 | Improvement proposition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <br>Position | <p>Vertical and horizontal positions have meaning of precedence between tasks (from left to right and from up to bottom).</p> <p>Precedence is a crucial concept on tasks models, no proposition is made to change the representation of precedence.</p>                                                                                                                                                                                                                                                                                 |
| <br>Size     | <p>Size has no relevance on the current model</p> <p>Winn has analyzed how people naturally interpret spatial relations in [14]. The findings were grouped in Sequence, Subclass, Intersection and Hierarchy [11]:</p> <div data-bbox="327 1523 742 1758"> </div> <p>Except for the inclusion of text describing the relationship type (   ,  &gt;,  &gt;,  &gt;,  &gt;,  &gt;,  &gt;) there is no difference between a node-leaf connection (structure relationship) and a node-node/leaf-leaf connection (behavior relation-ship).</p> |

|                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                   | <p>ship).</p> <p>Size is relevant for representing structural composition, while connections are more fitted to represent sequence/causality.</p> <p>In the image below, spatial enclosure and overlap (right side) convey the concept of overlapping subtypes in a more semantically transparent way than connecting lines [11].</p> <div data-bbox="981 526 1460 660"> </div> <p>Therefore, a significant improvement would be made if a notation could represent <b>structure</b> with subclass/subset and <b>behavior</b> with sequence/ causality.</p>                                                                                                                                    |
| <br>Shape        | <p>The shape variable maps to the nature property of the task, with one symbol for each: NONE, USER, SYSTEM, INTERACTIVE</p> <p>No changes are suggested; each task type should be distinguishable.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <br>Brightness | <p>Brightness has no relevance on the current model.</p> <p>Together with an eventual tool support the model entities in the diagram could have different brightness levels according to one of the following attributes:</p> <p>optional: the optional elements would have 50% brightness, the mandatory 0%;</p> <p>iterative: the less iterative tasks would be brighter than the ones with more iterations;</p> <p>criticality: the less critical tasks would be brighter than the more critical ones;</p> <p>frequency: the less frequent tasks would be brighter than the more frequent ones;</p> <p>centrality: the less central tasks would be brighter than the more central ones;</p> |
| <br>Texture    | <p>Texture has no relevance on the current model.</p> <p>Texture can be used to support the task's relationship by overloading the information present in the operators (   ,  &gt;,  &gt;,  &gt;,  &gt;,  &gt;,  &gt;)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <br>Color      | <p>Color has no relevance on the current model.</p> <p>Color can be used to complement shape, giving each task type a different color.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|                                                                                                  |                                                    |
|--------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <br>Orientation | Orientation has no relevance on the current model. |
|                                                                                                  | No changes are suggested.                          |

## DIAGRAMS AND TOOL SUPPORT

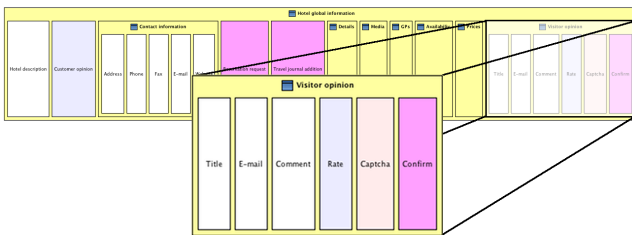
We believe tool support to be important to make UsiXML popular and foster model usage. For this purpose, there is work in progress on making the proposed visual notations usable with editors.

The propositions made by this work cannot be fully applied without proper tool support, for which we are developing a set of editors for each model in order to provide an integrated environment based on Eclipse. This platform was chosen because it is a multi-platform environment already well-know from the developers and provides a set of frameworks allowing developing modeling tools such as EMF, GMF, ... Moreover, it supports modeling standards defined by the OMG (Object Management Group).

The current state of the proposed diagrams is presented on the next section together with their tool support. As it is a work in progress, not all the improvement suggestions are implemented with the tools.

### AUI Diagram

The preliminary proposition for Abstract UI model is shown on Figure 9 (modeled for the same scenario of Figure 5)

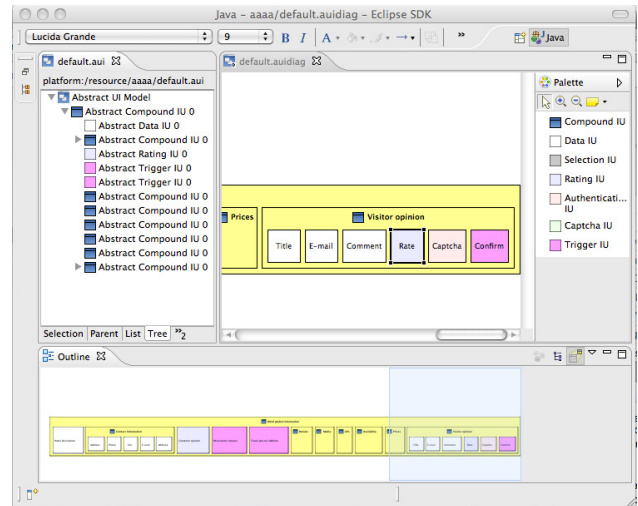


**Figure 9. Preliminary proposition for Abstract UI, with different colors for each AUI type.**

Since the bi-dimensional space does not exist on the abstract level, the diagram should not let the designer to specify position constraints.

The AUI notation in this work was designed in order to be truly independent of modality on the visual level as well (not only in the meta-model level). The tool support for AUI is showed on Figure 10, as an Eclipse integrated graphical editor. The left side shows the model being edited graphically on the right side; there is a palette with the elements from the meta-model to be dragged to the diagram.

All the elements are self-organized so the designer does not need to worry about the fine positioning, only on the **order** of the elements (horizontal positioning), as recommended by the analysis.



**Figure 10. Abstract UI editor on Eclipse.**

### Task Diagram

As said in the analysis, a significant improvement would be made if a notation could represent **structure** with subclass/subset and **behavior** with sequence/causality. In this sense, with proper tool support the designer would be able to switch between both views (structural and behavioral) on the same model.

Therefore, the Task model proposition is presented in Figure . It is similar to [9] in respect to the structure, since it represents a tree structure without connecting lines, but instead using grouping. However present on the meta-model level, the notation still doesn't visually shows the task type (system, user, abstract, interactive).

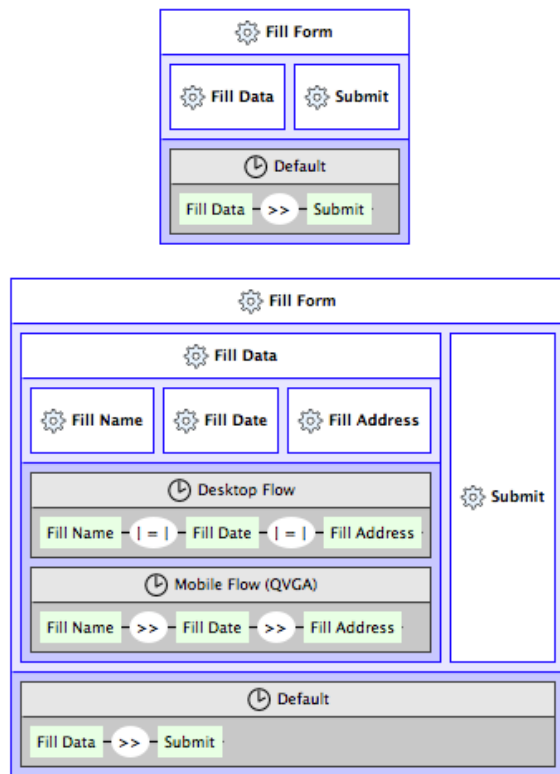
With this notation is possible to define alternative paths (or Temporalizations) for tasks depending on context situations. In the upper part of Figure 11 we show a task *Fill Form* with two subtasks *Fill Data* that enables *Submit*.

In the bottom part we show the same tasks, except that *Fill Data* has three other subtasks. Inside *Fill Data* two different flows are presented, for *Desktop* – in which the order of field filling does not matter; and *Mobile* – in which the order must be strict, since it is constrained by the device's screen size.

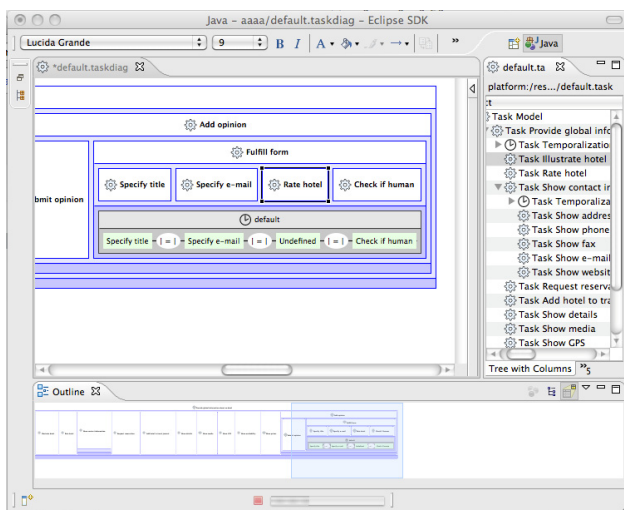
## CONCLUSION

This work aimed to present an analysis of currently available visual notations of UsiXML models in terms of a popular framework in graphic design.

By reviewing the driving question (*Are all the elements and relations of the meta-model represented on the visual notations?*) we can observe that:



**Figure 11. Preliminary Task Model with simplified and detailed visualizations.**



**Figure 12. Task Model editor in Eclipse.**

- In IdealXML not all the concepts on the meta-model are reflected in the diagrams. We have presented some possibilities of representation using visual variables;
- Vertical Position and Shape were ambiguous on IdealXML's notation. This work proposed solution for this problem;

- The Task model is more semantically transparent [11] because it uses components instead of lines to represent subsets of tasks;
- Variables such as Texture and Brightness can be used to represent importance, criticity or frequency.

As future works, as said in Section 2, this paper focused only on the design space. An inspection for the solution space needs to be taken, based on Physics of Notation [11].

Also, the remaining improvement suggestions are to be included on the notations such as *Shape*, *Brightness* and *Texture* for AUI and *Brightness*, *Color* and *Texture* for Tasks.

### ACKNOWLEDGMENTS

The authors would like to acknowledge of the ITEA2-Call3-2008026 UsiXML (User Interface extensible Markup Language) European project and its support by Région Wallonne DGO6.

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