

Physualization: Going Beyond Paper Prototyping

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Abstract—We present physualization, the deliberate physical manipulation of visualization entities, as a means of helping stakeholders explore possibilities in the requirement and design spaces. By engaging more of the stakeholder’s sensory and cognitive processes, our goal is to provide a means to enhance the requirements process and the resulting artifacts. Physualization relies upon readily available materials and *ad hoc* techniques to facilitate a lightweight requirements process.

This work provides guidance for an interactive session that explores physualization support for specific requirements engineering topics; developing paradigms for supporting these tasks using materials like stickies, transparencies, markers, and sketchpads as building blocks.

Keywords: Requirements process, requirements methodology, requirements visualization.

I. INTRODUCTION

Over the years we have investigated many rapid prototyping techniques for their utility in the requirements process: storyboards [1], paper prototyping [3], rich pictures [2] and rich media [4] to name a few.

Paper prototyping is possibly the most common form of rapid prototyping technique and is particularly adept at rapid exploration of the visual aspects of software applications, particularly user interfaces. However, there are more aspects to requirements than the user interface – support for aspects of requirements such as negotiation, traceability and rationale is needed and mechanisms for the rapid capture and representation of spatial options and temporal activities is desirable. These aspects have varying degrees of support in tools such as *Doors* and *RequisitePro* but what about lighter-weight alternatives?

II. PHYSUALIZATION

We define *physualization* as the physical manipulation of visualization entities – this is not just visualization for the sake of communicating or creating a record. Physualization actively promotes physical manipulation to help participants explore possibilities in the requirement and design spaces by engaging more of their sensory and cognitive processes – possibly leading to improvements in the requirements process and resulting artifacts. Because of its reliance on materials at hand and *ad hoc* techniques, physualization is most likely to be considered a form of agile requirements process.

This interactive session explores the extension of traditional paper prototyping to physualization with the goal of improving support for requirements activities such as those listed in Table I. The session explores support for specific requirements engineering topics, developing paradigms for supporting these tasks using materials like stickies, transparencies, markers, and sketchpads as building blocks.

Elicitation	Capture	Representation
Specification	Verification	Validation
Triage	Negotiation	Prioritization
Traceability	Rationale	Invention
Revisions	Modeling	Constraints

Table I
REQUIREMENTS TASKS

In Section VI we provide suggestions for possible techniques and in Section VIII we document example physualization output.

III. SESSION GOALS

Participants in a physualization session explore how to use common office materials to symbolically represent many of the design paradigms and patterns used in their domain. Participants are challenged to develop physical visualization metaphors to support requirements activities such as those listed in Table I. That is, what tools and techniques can be used to capture and represent RE tasks and principles? These metaphors can be broadly grouped in artifacts (what can be produced, captured) and activities (how are they represented e.g. how to represent negotiation, prioritization).

Participants are further encouraged to explore whether other computing concepts and tasks such as objects, database records, or even the database normalization process can be readily supported.

IV. SESSION RESULTS

Session participants are expected to

- Develop specific techniques to support their requirements activities.
- Develop increased appreciation for the utility of common office materials in support of their requirements activities.

- Develop a shared language and methodology for communication using these materials.
- Develop a better understanding of how increasing the number of sensory inputs that are actively engaged in a process can enhance creativity and improve participation.

A typical session will occupy 60 to 90 minutes for the participants – be prepared to have pressure to continue, some groups have kept investigating for far longer!

V. RESOURCES AND TOOLS

The suggested resources and tools for physualization are typical office materials.

- Large sketchpads for use as a work surface.
- Sticky notes of different colors and sizes – we have found extra large sticky notes to be quite useful.
- Writing instruments of various colors and sizes.
- Transparency sheets of the type used for overhead projection.
- Permanent and washable markers of the type used for transparency sheets.

Any other items that may be available may also be employed.

VI. QUESTIONS FOR CONSIDERATION

The following points suggest some questions that participants can keep in mind when attempting to generate new techniques.

- What meanings can be encoded into color, size, and other visual attributes?
- Are the X and Y dimensions on the work surface the only ones available? Consider stacking elements rather than replacing them.
- What can transparency sheets be used for?
- How to represent invariants vs. variates?
- Can items (such as stickies) be reused?
- Are there patterns or building blocks inherent in what you are attempting to accomplish? Can the patterns be abstracted? Into the materials?
- How to communicate that items are associated?
- How to communicate that items are part of a collection?
- Is there value in generating a record of Work In Progress (WIP)?
- How are you going to generate a record of WIP and final results?
- How to express the elements of a given modeling language?

VII. LEADING A SESSION

The following outline should help organizers to lead a session.

- 1) Prepare working materials such as sketchpads, stickies, transparencies, etc. and partition materials into

packages for distribution to each working group. Ensure that contribution recording forms, used to capture submissions, are part of each package.

- 2) Introduce concepts to the participants.
- 3) Demonstrate sample metaphors.
- 4) Partition attendees into working groups.
- 5) Assign topics to working groups.
- 6) Distribute materials to working groups.
- 7) Distribute contribution recording forms to working groups. Explain how to record contributions.
- 8) Allow work period. Attempt to record intermediate results via camera or video.
- 9) Allow each working group to present and demonstrate their results, allowing time for discussion of each group's results.
- 10) Present summary comments.
- 11) Mediate discussion of strengths, weaknesses, suggestions for improvement. Record comments.
- 12) Gather recording forms to composite summary record.
- 13) Distribute copies of summary report to participants.

VIII. SOME EXAMPLES

The following examples are taken from work performed in gathering requirements for video games. The focus in these sessions was on capturing the intended user experience, in general, and the intended emotional experience in particular. In Figure 1(a) we see a template description for emotional requirements and a covering sticky note with layers of stickies and handwriting. The yellow sticky note is for a *gameElement* titled SALT CONTAINER and it has an associated image to provide artistic guidance to the production team. From the background template description, we see that a *gameElement* has associated *mediaAttributes* and *gameAttributes*. These attributes are on secondary, supporting stickies that are themselves color-coded. The use of secondary stickies allows the requirements elicitation process to be very dynamic - there are no concerns with rapid iterations and complexities of erasing and replacing, simply peel off and replace with a new iteration.

The sticky notes also allow us to bind together requirements elements; the *mediaAttributes* and *gameAttributes* are clearly bound to the larger *gameElement*. Figure 1(c) shows a selection of intended emotional states. The iconic nature of the elements shows that they are intended to act as library elements, promoting reuse during sessions.

In Figure 2, we see portions of workspaces associated with simple gameplay elements from a 2D side-scrolling game. These scenarios make use of a number of principles. The invariant element is sketched on a background workspace. The player avatar is iconified in various actions (jumping, in this example) and the intended emotional states for the player are drawn from the library previously introduced. Patterns for gameplay activity, such as *repetition* and *challenge followed by mastery* are also used and shown in

contextually appropriate locations across the bottom of the background workspace. Success (Figure 2(a)) and failure (Figure 2(b)) modes are shown and the player's emotional state is indicated. For example, the player experiences an alternating emotional state, passing between JOY and FEAR as the oranges roll toward them. JOY is associated with successfully jumping over the orange, FEAR is associated with the recognition that the orange is rolling ever closer and that the player must soon successfully jump, or have their player killed. The Challenge followed by Mastery pattern identifies the type of challenge – the player must repeatedly meet the challenge but they eventually master the technique. The amplitude of the the sine wave represents the decreasing intensity of the experience.

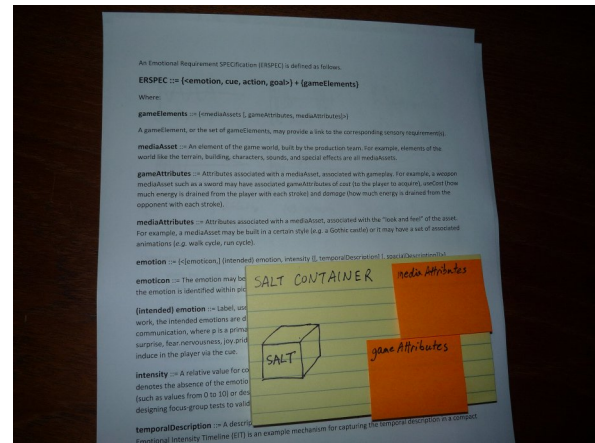
Figure 2(c) illustrates alternative gameplay in the same scenario. In this example, two elements have changed: the challenge is now a banana which has more difficult gameplay than an orange (Increasing Challenge sticky) and the player is punching the banana rather than jumping over it. Note that the banana sticky is layered on top of the (partially hidden) orange sticky. The underlying sticky is deliberately exposed to indicate that the banana and orange are options, each of which can occur during gameplay. If the orange sticky was completely hidden by the banana, then this would indicate that the original design decision to use an orange has been changed to that of a banana.

The metaphor chosen: partial vs. full overlap to indicate the difference between runtime gameplay options and gameplay design history was arrived at by the participants in an earlier session. The design history metaphor supports the common requirements task of maintaining a revision history. Partial overlap is a concise representation of the conjunction of requirements.

The basic principle of placing the invariants on the background of the workspace are also illustrated in Figure 3. Figures 3(b) and 3(c) illustrate the use of transparencies to present gameplay requirements for different gameplay scenarios. Each gameplay scenario is described on the transparent overlay and different options can be explored with ease. Figure 3(b) also illustrates that validation and verification activities can be added with another color of sticky.

REFERENCES

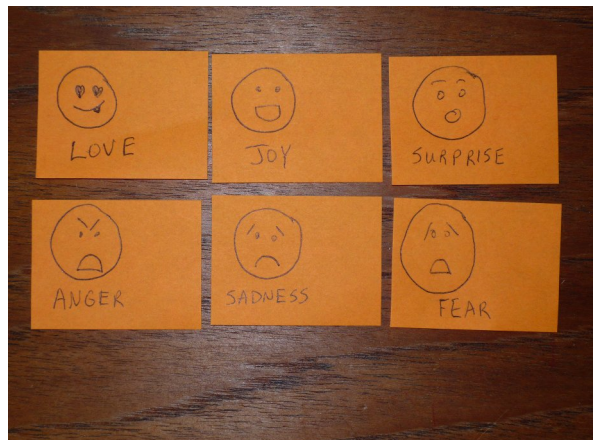
- [1] S. Andriole. Storyboard prototyping for requirements verification. *Large Scale Systems in Information and Decision Technologies*, 12(3):231–247, 1987.
- [2] Andrew Monk and Steve Howard. Methods & tools: the rich picture: a tool for reasoning about work context. *interactions*, 5(2):21–30, 1998.
- [3] Paper Prototyping. *Carolyn Snyder*. Morgan Kaufmann, 2003.
- [4] Konstantinos Zachos, Neil Maiden, and Amit Tosar. Rich-media scenarios for discovering requirements. *IEEE Software*, 22(5):89–97, 2005.



(a) Emotional requirement specification format, getting started



(b) A closer look at a gameElement



(c) Reusable emotion icons

Figure 1. Starting to physualize

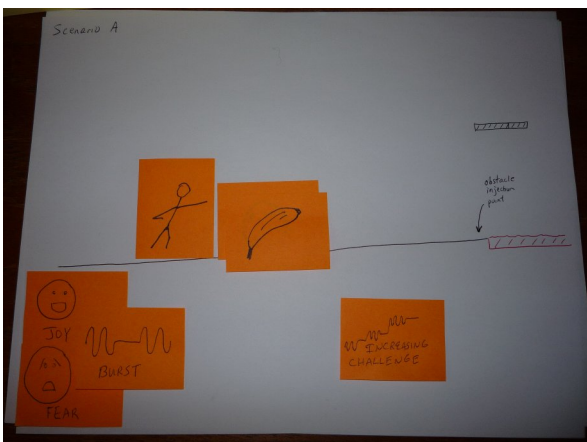
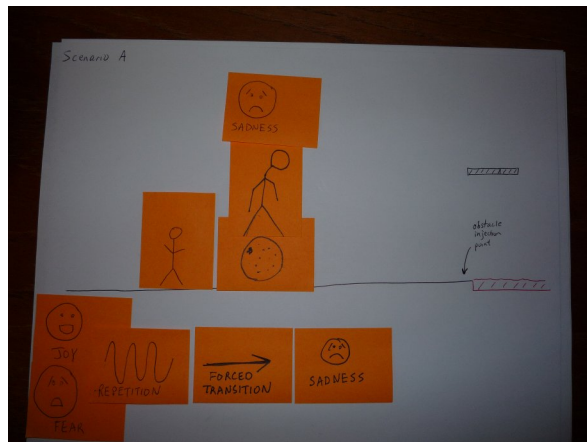
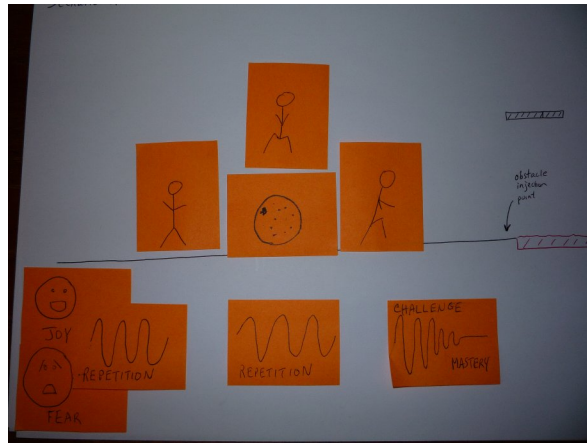
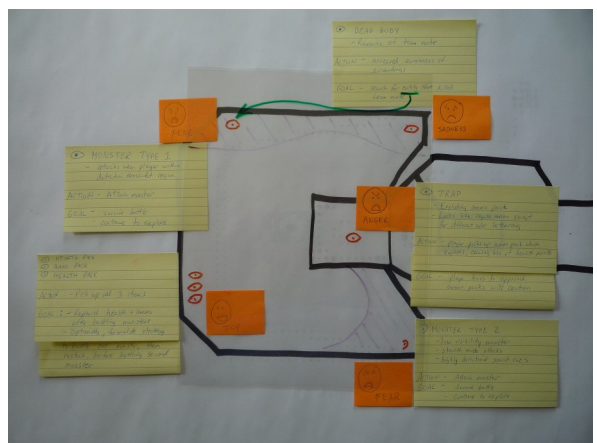
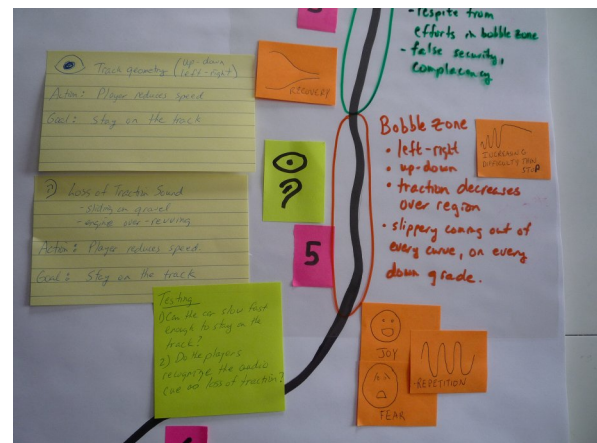
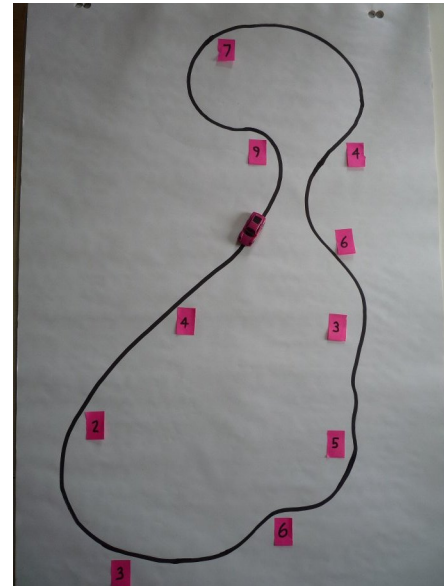


Figure 2. Simple gameplay scenarios



(c) A closer look at experience requirements in a first person shooter game scenario

APPENDIX

Other Work of Interest: In addition to the traditional bibliography, we include links to a small selection of related materials on the Internet and links to a selection of YouTube video clips presenting related work on the use of paper prototyping.

A. Printed Materials

- *Paper Prototyping by Carolyn Snyder*
<http://www.paperprototyping.com/index.html>
- *Paper prototyping (a general introduction to the process)*
<http://www.usabilitynet.org/tools/prototyping.htm>
- *Hipster PDA* http://en.wikipedia.org/wiki/Hipster_PDA
- *Post-it Note Design Docs*
<http://www.lostgarden.com/2008/12/post-it-note-design-docs.html>
- *Paper Prototyping by Shawn Medero, A Basic Introduction*
<http://www.alistapart.com/articles/paperprototyping/>
- *Considering Prototypes*
<http://www.uxbooth.com/blog/considering-prototypes/>
- *Data Sculpture* Zhao, Jack and Moere, Andrew Vande. Embodiment in data sculpture: a model of the physical visualization of information. In DIMEA '08: Proceedings of the 3rd international conference on Digital Interactive Media in Entertainment and Arts, 2008, pp. 343-350, ACM, New York, NY, USA

B. Physical Visualizations

- *Glowing temperature sink fixtures*
http://www.boingboing.net/2005/07/13/glowing_temperatures.html
- *Waveform display of a musical piece* <http://well-formed-data.net/archives/150/physical-visualization>
- *Visualization Problems? Get Physical!*
<http://ezinearticles.com/?Visualization-Problems?-Get-Physical!&id=1383153>
- *Physical Data Art by Willem Besselink (by Maria Popova)*
<http://www.brainpickings.org/index.php/2009/11/11/willem-besselink/> and
http://www.willembesselink.nl/read/willem_besselink-portfolio

C. YouTube Videos

- *iPhone Paper Prototype Post-it*
<http://www.youtube.com/watch?v=If2iRj1GWzk>
- *Trouble (Game) Paper Prototyping*
<http://www.youtube.com/watch?v=dTR7gbsF7Os>
- *Paper Prototype for Mobile Journalism*
<http://www.youtube.com/watch?v=3-UWIVMhYkA>
- *Paper prototype created by using the Scrum process.*
<http://www.youtube.com/watch?v=ykJ60H4Qkvg>

- *IAT 410 paper prototype, game design*
<http://www.youtube.com/watch?v=4ROZqOwHyWo>
- *DAC 300 Paper Prototype - Tap That!*
<http://www.youtube.com/watch?v=EiMyMk10d0I>
- *Paper prototyping: Game design*
<http://www.youtube.com/watch?v=k-9pkB05IIQ>
- *Have Paper, Will Prototype*
<http://www.youtube.com/watch?v=L3yl9vaJuFE>