SUPPORTING MULTIMEDIA DESIGNERS: TOWARDS MORE EFFECTIVE DESIGN TOOLS

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Current multimedia tools have fallen short of meeting the unique needs of a multimedia designer, presumably due to a misunderstanding of what those unique needs actually are. To better understand a designer's needs and practices, we interviewed (12) and surveyed (13) professional multimedia designers. From this study, we report on the process of multimedia design, design artifacts produced in that process, and tools used to produce those design artifacts. An important finding of our study is that a multimedia designer struggles to explore and communicate behavioral design ideas early in the design process. To address that need, we have developed an interactive multimedia storyboard tool called DEMAIS, which operationalizes a designer's ink strokes and textual annotations, producing a working example early in the design process. Using a working example, a designer can directly experience a behavioral design idea, facilitating the rapid exploration and effective communication of that behavioral idea.

1   Introduction

When compared to the design challenges faced by a user interface or web site designer, the design challenges faced by a multimedia designer are unmistakably unique. In addition to addressing the design challenges of creating a coherent information structure, robust navigation among that structure, and attractive visual content and spatial layout, a multimedia designer must also address the challenges of:

- Designing, creating, and seamlessly integrating dynamic content such as animation, narration, background music, and video as well as effectively using screen transitions such as wipes, fades, and dissolves.
- Structuring both the static and dynamic content in the temporal dimension (temporal layout), and expressing how that structure is affected by user interaction.
- Creating innovative user interaction beyond link navigation. Transforming the user from a passive observer to an active participant is the key to creating a compelling multimedia application [2].
- Satisfying a seemingly insatiable demand for creativity in terms of content and behavior, given the constraints of a short time frame and limited budget.

In this paper, we use the term "behavior" to collectively refer to the multimedia design space dimensions of user interaction and timed-based information display.

Although we understand what the unique design challenges of a multimedia designer are, we need to better understand how a designer actually meets those challenges in practice. The motivation for gaining a better understanding of multimedia design practice is that the multimedia design community has all but ignored design formalisms such as formal design models [5, 19, 21] and methodologies [10, 22] produced from research. At the same time, the multimedia design community still embraces ineffective design methods such as using static screen mockups to simulate complex behavior or using an authoring tool as a rapid prototyping tool. We believe the reason for this discordance is that current research has drifted from understanding the true needs of a multimedia designer.

In this work we take a fresh approach, beginning with understanding the needs and practices of a multimedia designer through a series of interviews and surveys, analyzing those needs and practices, and then using that analysis as input for the design of a new multimedia design tool called DEMAIS. DEMAIS (DEsigning Multimedia Applications with Interactive Storyboards) is a sketch-based, interactive multimedia storyboard tool that uses a designer's ink strokes and textual annotations as an input design vocabulary. By operationalizing this vocabulary, the tool transforms a set of static storyboard sketches into a *working* example, enabling a designer to directly experience the behavior represented on those sketches.

Although previous research has provided similar ethnographic studies in the domains of user interface and web site design [13, 18], the unique challenges inherent in the domain of multimedia design warranted further study.

2   Related Work

Several domain studies similar to our current domain study of multimedia design have been previously conducted in an effort to produce more effective design tools or enabling technologies.

In a study of video design practice, MacKay and Pagani [16] observed that a video producer still relies on paper storyboards as a design tool even with the abundance and availability of computer-based video editing tools. The authors used their observations regarding the needs and practices of a video producer to develop a new video design tool called Video Mosaic. Video Mosaic provided an augmented reality environment enabling a video producer to experience the video resulting from editing decisions made early in the design process.

Landay [13] surveyed user interface designers to better understand how and why a user interface designer sketches early in the design process. His study resulted in a new

user interface sketching tool called SILK, which when evaluated in a design study, demonstrated a positive influence on the design of a user interface application [12].

Newman and Landay [18] conducted a series of interviews with professional web designers in an effort to identify design areas where an informal sketching tool could be applied. The study resulted in a promising new web site design tool called DENIM [15].

Gustafson et al. [8] conducted a field study in the domain of newspaper production in an effort to streamline the production process. Not only did the resulting agent software substantially reduce production time, but it also achieved wide acceptance among the production staff.

Although a goal of our study was to identify areas in the multimedia design process where a new design tool could prove useful, we did not approach our study with any preconceived notion about the type of design tool that might be built, if any.

3 Study of Multimedia Designers

Our study of multimedia design practice consisted of both interviews with and surveys of professional multimedia designers. The interviews were conducted first to gain a better understanding of the multimedia design process, design artifacts produced in that process, and tools used to produce those design artifacts. Our experience gained from the interviews was then leveraged to create a design survey. The survey enabled us to gain feedback from a broader range of multimedia designers, focus on the interesting issues discovered in the interviews, and gather data in a quantifiable format.

3.1 Interviews

We interviewed 12 professional multimedia designers from eight companies located in the Minneapolis area. The interviews were conducted to gain a better understanding of multimedia design practice including the steps followed, roles fulfilled, artifacts produced, and tools used in the design process.

During an interview, we asked the designer to step us through a recently completed or ongoing project. As the designer walked us through the project, we asked to see design artifacts such as scripts, storyboards, old prototypes, sketched notes, and more. At each step, we asked about the information being communicated, the effectiveness of the artifact(s) at communicating that information, and the effectiveness of the tools used to produce those artifacts.

A common thread among the designers was a pious desire to create *innovative* content and behavior in their multimedia applications. The designers expressed that although designing a web site can be challenging, it is often boring from a design perspective because of the World Wide Web's limited support for dynamic content and

user interaction (although this is changing). A multimedia designer considers the freedom to create innovative content and behavior to be what makes multimedia, "multimedia," and a multimedia design company considers the creativity of its designers to be a competitive advantage.

3.2 Surveys

After the interviews were completed, we created a design survey focusing on how a multimedia designer explores and communicates behavior early in the design process. The survey was posted to several multimedia design newsgroups and e-mailed to additional designers nominated in the interviews. We received 13 responses to the survey. The survey asked a designer to:

- Describe his/her educational background
- Select his/her domain(s) and years of professional experience
- Select and order the design artifacts produced early in the multimedia design process
- Rate the vitality of each artifact to the successful design of a multimedia application
- Identify the tools used to produce each design artifact
- Rate an artifact's ability to help him/her explore and communicate behavior in the design process
- Send us examples of design artifacts with the agreement that they would remain confidential

4 Study Results

In this section we report the results of our multimedia design study. We discuss the professional background and experience of the designers, itemize the design artifacts produced in the design process, discuss the tools used to produce those artifacts, delineate the process of multimedia design, and describe how a designer chooses a mechanism for exploring and communicating behavior in the design process. We report on our study in a collective manner, noting differences between the interviews and surveys only when meaningful. To provide context, we begin this section with a brief clarification of our use of the term "designer."

4.1 Clarifying a "Designer"

A "designer" is not a single person but a team of talented people typically consisting of a project manager (producer) and a mix of writers, graphic artists, interaction designers, programmers, and audio/video production staff. A person may fulfill more than one role

on a design team such as being both the graphic and interaction designer. A person may also be involved in multiple ongoing projects and their corresponding design teams.

A design team is formed on a per project basis, matching the requirements and scope of the project to the skills and availability of the people. In Figure 2, we distinguish among the different roles fulfilled on a design team, however in the text, we use only the term *designer* for brevity and consistency.

4.2 Background and Experience of Designers

Most of the designers involved in the study had at least 5 years of experience developing interactive CD-ROMs, web sites, or instructional training applications, producing television commercials, or managing projects involving interactive media.

One lesson from conducting the study is that few designers have any formal education or professional experience in the area of programming languages, although a few designers were compelled to gain a working knowledge of a relevant language such as Lingo [17] or HTML [9]. Most of the designers had a background in one or more of art, graphic design, project management (producer), or video production. The background and experience of the designers are summarized in Table 1.

Table 1: Background and Experience of Designers in the Study

Background					Yrs Experience			
Art	Development	Graphic Design	Project Mgmt	Video	0-2	3-4	5-7	> 7
4	6	11	10	5	4	1	8	12

4.3 The Artifacts of Multimedia Design

Design artifacts are produced in the multimedia design process to help a designer explore and refine a design idea, compare two or more design ideas, or communicate a design idea to a client or team member. Throughout the multimedia design process, a designer may produce any of the following design artifacts:

- *Mind map*. Used to initially explore the hierarchical structure of and semantic relationships among the message content that a client wants to convey through a multimedia application.
- *Information hierarchy*. A more formal and refined version of the mind map defining the hierarchical structure of and semantic relationships among the message content.

- *Content map*. A graphical representation of an application's content structure derived from the information hierarchy. A representational element in the content map is a small rectangle representing a screen along with a description and sketched layout of the content to be placed on that screen. A content map further organizes the information hierarchy into individual screens of information and is closely related, and sometimes identical, to the *site map* produced in web site design [18].
- *Navigation chart*. Depicts how a user can globally navigate among the primary content screens and is often integrated with the content map.
- *Flowchart*. Informally defines interaction scenarios for a specific content screen or which span multiple content screens. The flowchart may be annotated with textual notes describing special programming instructions or repetitive aspects relevant to other content screens.
- *Prototype*. A working demonstration of a design idea that enables a designer to directly experience the feel of that design idea. Experiencing a design idea helps a designer to explore and effectively communicate the behavioral aspects of that design idea to other team members as well as the client.
- *Storyboard*. A visual representation of content, the spatial layout of that content, and behavior. A low-fidelity storyboard such as a pencil and paper sketch often contains annotations and graphical marks describing the behavior associated with the content on that storyboard. As the fidelity of a storyboard increases, the annotations and graphical marks may be moved to another design artifact such as the script.
- *Storybook*. A collection of storyboards created for the design of an application.
- *Script*. Provides the location of content (file names), a textual description of behavior, the textual content of accompanying voice narrations, and any special programming instructions for each storyboard in the storybook. The script ties together several design artifacts and is generally considered to be the final design document.

For a given project, a multimedia designer may produce only a subset of these artifacts. The decision of which artifacts to produce and the level of detail to which those artifacts are refined depends on the scope of the project, experience of the designer, and design culture cultivated by the company.

A targeted set of the design artifacts outlined above and the stated order that a designer produces those artifacts early in the design process are summarized from our design survey in Figure 1. A targeted set of design artifacts was used in the design survey because we wanted to focus on artifacts produced early in the design process and how a designer explores and communicates behavior using those artifacts.

In Figure 1, a definitive order in which design artifacts are produced early in the design process does not appear, providing further evidence that the multimedia design process is very ad hoc and informal, as we observed this in our interviews as well.

Order / Artifact	First	Secnd	Third	Fourth	Fifth	>= Sixth
Outline (script)	++++ +++ ***	**	+++ **	*		*
Information Hierarchy	+++ **	++++ *	***	**	+	
Navigation chart	+ ***	+++ **	+++ *	+	+	
Storyboard	+ ******	++++ *	+++++	**		
Protoype	**	+++ *****	++ *	+++++	***	++
Voice script		+	++ *	+	+++ *	***
Flowchart		+ ***	+	+++ *	+	+ *

Figure 1. Results of the design survey showing the order in which a targeted set of design artifacts are produced in the multimedia design process ('+'), and how vital those artifacts are to the successful design of an application ('*').

However qualitatively, the early design process begins with the exploration of content structure and then moves to the near parallel exploration of visual layout and behavior.

Designers rated storyboards as the most vital design artifact for the successful design of a multimedia application, and almost all designers created storyboards early in the design process. As a result, we chose a storyboard metaphor for the design of our multimedia design tool, DEMAIS.

Designers rated a prototype as being relatively vital to the successful design of an application, yet in the interviews, we observed that only about half of the designers built a computer-based prototype in the design process, and only a few designers built a computer-based prototype early in the design process. Designers stated that the primary advantage of building a prototype is to experience how a design will *feel* for an end user before production on that design begins. Unfortunately, waiting until late in the design process to build a prototype precludes a designer from making behavioral changes that are outside the boundaries set by the prototype. In other words, design decisions are based on what is "doable" given the time, money, and effort already invested into building the current prototype, not necessarily on what is best. These observations are reminiscent of the low vs. high-fidelity prototyping debate in user interface design [20].

4.4 The Tools of Multimedia Design

A multimedia designer uses a variety of tools in the design process. In the early stages of design, a designer uses more low-fidelity tools such as pencil and paper for sketching, sticky notes for structuring content, colored string for identifying semantic relationships, and onion skin paper for building physical demonstrations. As the design process iterates and a particular design idea begins to solidify, a designer transitions from using low-fidelity tools to using higher-fidelity tools such as Adobe Photoshop, Adobe

Illustrator, Visio, or Authorware. For example, a designer often uses pencil and paper to sketch initial versions of a storyboard, but then transitions to using Adobe Photoshop or Adobe Illustrator as the design idea captured on that storyboard begins to solidify or when that design idea needs to be presented to the client.

If a multimedia designer does build a prototype, she typically uses Authorware as it's viewed as a more rapid prototyping tool than Director and a more powerful prototyping tool than HyperCard. However, only a few designers actually built prototypes early in the design process, a point that is addressed further in Section 4.6.

4.5 The Process of Multimedia Design

The process of multimedia design can be abstracted into the four design phases observed for the process of web site design; *discovery*, *design exploration*, *design refinement*, and *production* [18]. The multimedia design process is outlined in Figure 2.

In the discovery phase, a multimedia designer collaborates with the client to determine the needs of that client, determine the scope of the project, define the intended audience, define the message for that audience, and discuss the creation of content as well as the re-purposing of any existing content. As part of the discovery phase, a designer produces several design artifacts such as a script outline, content map, and navigation chart.

In the design exploration phase, a designer begins exploring one or more creative design ideas satisfying the project description, each differing along one or more dimensions of the design space as well as the projected timeframe and cost of implementing that design. To explore a design idea, a designer uses one or more design artifacts (representations) such as flowcharts, navigation charts, and storyboards. A designer produces and uses design artifacts to help determine whether a particular design idea "works" in terms of content, the structure and spatial layout of that content, and behavior, and to communicate and present that design idea to the client as well as other team members. Early in the design process, the client must select one of the presented design ideas for further refinement. Thus, the communication of design ideas is extremely important, as the client must have a clear understanding of each design in order to make an informed selection.

Together, static (non-functional) design artifacts such as flowcharts, content maps, and storyboards provide an effective mechanism for communicating the non-behavioral dimensions; i.e., content and the structure and spatial layout of that content, of a design idea. However, using static design artifacts to explore and communicate the behavioral dimensions of a design idea is more problematic. The problem arises from the discordance of using *static* representations to convey *dynamic* (behavioral) concepts such as how an application responds to user interaction or the passage of time.

Process Step	Action	Outcome	Responsibility
Discovery			
Define message and user experience	Understand client needs Define communicative goals	Needs analysis document	Client, producer
Analyze message and information structure	Define the structure of and relationships among the message content	Mind map Script outline Information hierarchy Navigation chart	Producer
Explore & Refine			
Brainstorm	Collaborate on creative design ideas	Two or three design ideas of differing complexity	Producer, graphic artists, writers
Explore a design idea using visual representations	Sketch content & layout Sketch/annotate behavior Scribble design notes	Flowchart Storyboards	Graphic artists, producer, writers
Create content	Create animations, audio, video, graphics, text	Animations, audio, video, graphics, text	Graphic artists, writers, production staff
Experience a design idea through its visual representations	Assess design quality and appropriateness	storyboard walkthrough Prototype	Client, producer, graphic artists
	Assemble design artifacts	Storybook Final script	Producer
Production Implementation	Build application	Application	Development team

Iterate

Figure 2. The multimedia design process. The design process iterates rapidly in the beginning when design ideas are still rough and evolving and slows as a particular design idea solidifies. The sequence of steps realized and the artifacts produced in the design process depends on the scope of the current project, experience of the design team and design culture of the company.

The result of this discordance is that the exploration and communication of behavior using static design artifacts requires the use of imagination and intuition, possibly causing a gulf of understanding.

A more effective mechanism for exploring and communicating a behavioral design idea is enabling a designer to directly experience that behavioral idea. For example, interacting with a computer-based prototype of an innovative navigation concept enables a designer to directly experience that concept, thus providing a sound reference for feedback and discussion. Choosing an effective mechanism for exploring and communicating behavioral design ideas will be discussed further in Section 4.6.

In the design refinement phase, each of the artifacts created in the discovery and design exploration phases are refined to a greater level of detail. For example, a designer may move from a storyboard sketch made with pencil and paper to a high-fidelity graphic illustration made with Adobe Photoshop or Adobe Illustrator. The level of detail to which an artifact is refined depends primarily on the complexity of the application being designed, but also depends on the experience of the designer and the design culture of the company.

In the production phase, a designer transfers the design artifacts to the development team for implementation. The design artifacts transferred usually include the content map, storybook, and script, but may also include any of the design artifacts discussed in Section 4.3.

The most salient feature of the multimedia design process is copious iteration, indicative of a spiral design model [23]. The multimedia design process iterates rapidly in the early stages of design, when the creative ideas are still rough and evolving [7], and slows as a particular design idea solidifies [23].

4.6   Choosing a Mechanism for Exploring and Communicating a Design Idea

A designer must choose an effective mechanism for exploring and communicating a design idea in the design process. A designer chooses a mechanism based on the design dimensions he needs to explore or communicate, the complexity of those design dimensions, and the position in the design process. For example, if a designer needs to explore and communicate complex content structure early in the design process, then she may group and attach sticky notes to a wall and connect those groups with colored string, each color representing a different semantic relationship among the content [4].

Although providing mechanisms to help a designer explore and communicate the *non-behavioral* dimensions of the design space is a current topic of research, e.g., see [11], our focus is on providing a mechanism to help a designer explore and communicate the *behavioral* dimensions of the design space. We summarize our
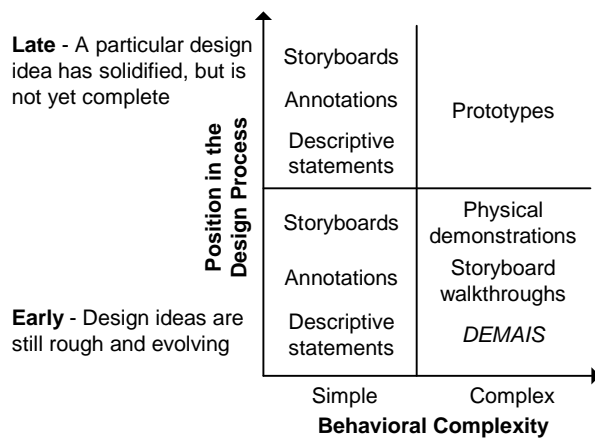
	Simple	Complex
Late - A particular design idea has solidified, but is not yet complete	Storyboards Annotations Descriptive statements	Prototypes
Early - Design ideas are still rough and evolving	Storyboards Annotations Descriptive statements	Physical demonstrations Storyboard walkthroughs *DEMAIS*

(vertical axis: **Position in the Design Process**; horizontal axis: **Behavioral Complexity**)

Figure 3. A prescriptive taxonomy for choosing an effective mechanism for exploring and communicating behavioral design ideas in the multimedia design process.

observations regarding mechanisms for exploring and communicating behavior in the design process with a prescriptive taxonomy shown in Figure 3.

If a designer needs to explore or communicate simple behavior, either early or late in the design process, then he should write textual annotations on the storyboards, create a sequence of storyboards, or write descriptive statements in the script to specify that behavior. However, choosing an effective mechanism for exploring and communicating more complex behavior is a more challenging task.

The challenge for a designer is to simulate or produce an experience communicating how a behavioral design idea will *feel* for an end user. For example, to communicate the feel of a particular navigation concept, a designer may simulate an experience of that concept by conducting a cognitive walkthrough using a sequence of storyboards or by scanning and then inserting the storyboards into a software tool such as Director or PowerPoint. These mechanisms are sometimes referred to as low-fidelity prototypes [20]. Although quick and easy to produce, a low-fidelity prototype does not enable a designer to directly experience a behavioral design idea and forces her to use imagination and intuition to gain a sense for how that idea will feel for an end user.

A more effective mechanism for exploring and communicating complex behavior is directly experiencing that behavior using a computer-based prototype, created with an authoring tool such as Authorware. For the remainder of this paper, we will use the term "prototype" to refer to a computer-based prototype enabling a designer to directly experience a behavioral design idea. Directly experiencing a behavioral design idea unambiguously communicates the feel of that behavioral idea, and thus provides a sound reference for making important design decisions and gaining quality feedback from clients and team members. A paraphrased (for clarity only) statement from a returned survey and two quotes from interviews regarding the benefits of using a prototype illustrates this point:

A working prototype makes a design easier to demonstrate to clients (the uninitiated in development) by "showing" them what they will be getting. It puts into perspective what content they need to review or provide and allows for better conversations about the functionality and the objectives of the program [paraphrased from a survey].

"We want them [clients] to experience what their users will experience as close as possible. We want them to know what they are getting and ultimately what they are paying for as soon as possible" [interview quote].

"Its very difficult to get the feel of an application from a paper-based diagram. Thus, it is very important for the client to sit down and play with a prototype" [interview quote].

Although building a prototype may be a reasonable mechanism for exploring and communicating complex behavior *late* in the design process, it is not a reasonable mechanism for exploring and communicating complex behavior *early* in the design process. Building a prototype early in the design process costs too much in terms of time, money, and effort, and slows the early design process just when it needs to be rapid. A quote from each of four designers interviewed in our study illustrates this point:

"I love to show working prototypes, but currently, flowcharts and information architecture are the primary things that I show clients up front. We are always limited by time and money and working prototypes are not feasible."

"Our methods of communication are often too little, the design typically stays on paper in the form of screen shots of important screens. And sometimes our methods [rapid prototyping] are too much in terms of time, effort, and money. Prototyping takes a great effort for constant changes."

"We have very little time for prototyping. As a result, we rely on thorough design documentation as a substitute."

"Prototyping right from the beginning increases the total amount of time [money] we need to charge. A great deal of work goes into something that will be thrown away. The code becomes a jumbled mess and gets to the point that the prototypes are buggy, hard to change, and need to be rewritten once the actual implementation starts."

As the behavior that a designer wants to explore and communicate becomes more complex, the use of static design artifacts and simulated experiences become less effective, resulting in a greater need to directly experience that behavior. If a designer cannot effectively explore or communicate a behavioral design idea, then a less innovative idea may be chosen simply because it is understood the best or perceived as having the least amount of risk in terms of an unsatisfied client or end users.

In sum, a designer needs a rapid and easy-to-use mechanism to directly experience a behavioral design idea early in the design process, facilitating the exploration and communication of that behavioral idea. Our new design tool, DEMAIS, provides such a mechanism and will be introduced after we summarize the key findings of our study.

5 Findings of the Study

In our multimedia design study, we found that:

- *The quality of a multimedia application hinges on a designer's ability to extract the intended message for an audience from a client in the discovery phase.* Many designers expressed the desire for an automated tool that would help them ask the "right" questions in the discovery phase.
- *Design formalisms such as formal design models and methodologies are not used in the multimedia design process.* Formalisms are not used because they (a) have a steep learning curve, given a designer's background; (b) are discordant with the nature of the design process; or (c) produce results that have little perceived benefit to a designer. A multimedia designer often has a non-technical background causing the language of a formalism to be difficult to comprehend and use. Designers are not convinced that using a formalism produces value greater than the cost of learning and coding a design using that formalism. Second, the nature of the multimedia design process is informal and ad hoc, which is discordant with the rigor, precision, and completeness required by a formalism. Finally, the value of using a formalism is that it produces a model which can be tested against some criterion such as whether that model is temporally consistent [6]. Designers are not convinced that integrating the results of model testing will contribute to a substantial improvement in the overall design of a multimedia application.
- *Textual annotations scribbled on a storyboard provide a rich source of behavior definition.* A multimedia designer often scribbles annotations describing the use of non-visual content such as audio and how an application behaves in response to user interaction or the passage of time. For example, a designer may annotate a storyboard with a statement such as "start the audio two seconds after this screen is displayed."
- *A designer wants to focus on creating innovative content and behavior during the design process, not on programming or learning a new software tool.* "The tool cannot get in the way of what a designer wants to do. Designers are not programmers or software experts" [interview quote].
- *A multimedia designer has a deep desire to create innovative content and behavior for an application.* A designer considers the freedom to create innovative content and behavior to be what makes multimedia, "multimedia," and a multimedia design company considers the creativity of its designers to be a competitive advantage.
- *Authoring and prototyping tools are not effective mechanisms for exploring and communicating innovative behavior early in the design process.* Prototyping innovative behavior early in the design process costs too much in terms of time, money, and effort, and slows the early design process when it needs to be rapid.

- *A multimedia designer needs a more effective mechanism for rapidly exploring, comparing and communicating behavior early in the design process.* A multimedia designer currently struggles to explore, compare, and communicate behavior early in the design process and often resorts to using a low-fidelity mechanism such as a storyboard walkthrough or physical demonstration to simulate an experience of that behavior [1]. However, exploring and communicating behavior using a simulated experience can be ineffective, as it requires a designer to *imagine* how that behavior will actually feel for an end user.

In response to this last finding, we believe a more effective mechanism for exploring, comparing, and communicating behavior early in the design process is *directly experiencing* that behavior. Directly experiencing behavior means that a designer can interact with a working example of that behavior as opposed to a low-fidelity simulation. To enable a multimedia designer to create working examples of behavioral design ideas early in the design process, we have developed an interactive multimedia storyboard tool called DEMAIS.

6   DEMAIS: A Tool for Multimedia Design

To provide an affordable mechanism for rapidly exploring and effectively communicating behavioral design ideas early in the design process, we have developed a new multimedia design tool called DEMAIS (DEsigning Multimedia Applications with Interactive Storyboards) [1]. DEMAIS is a sketch-based, interactive multimedia storyboard tool that uses a designer's ink strokes and textual annotations as an input design vocabulary. By operationalizing this vocabulary, the tool transforms a set of static sketches into a working example, enabling a designer to directly experience the behavior represented on those storyboards. Specifically, DEMAIS enables a designer to:

- Sketch and annotate a set of storyboards using a stylus and electronic canvas just as she would using pencil and paper
- Edit a storyboard using gestures
- Develop voice narrations and import images, audio, and video into a storyboard
- Sketch synchronization among the narrations, audio, video and other sketched content
- Sketch interactive and time-based behavior using ink strokes and textual annotations
- Edit behavior using an expressive visual language
- Operationalize the sketched behavior to obtain a working example

Next, we briefly discuss the tool components of DEMAIS and then illustrate the use of these components for the design of an interactive experience.

6.1 Tool Components

DEMAIS offers four tool components; a *storyboard editor*, *narration editor*, *multi-view editor*, and *content manager*. The storyboard editor is an electronic canvas on which a designer can sketch content and spatial layout, import audio, video, and image content, enter text and annotations, and sketch behavior among the content. The storyboard editor is shown in Figure 5. A designer imports audio, video, and image content by sketching a rectangle, tapping once within it, and then selecting the appropriate media file from the file browser that appears. The imported content is then scaled and positioned to the bounds of the sketched rectangle. A designer sketches behavior by drawing an ink stroke between two recognized objects on a storyboard such as a sketched rectangle, entered text, or an imported image or video. When an ink stroke connects two recognized objects, DEMAIS interprets that ink stroke as a *behavioral* ink stroke and assigns a default source event and destination action to it, signified by the appearance of the appropriate visual language icons. A designer modifies the source event or destination action by first tapping on the desired visual language icon from the icon panel located along the bottom of the screen (see Figure 5) and then tapping on the icon to replace. DEMAIS provides source event icons for single and double mouse clicks, rollovers, drag and drop, timers, and synchronization with dynamic content (begin, end, and time point reached), and action icons for navigating and transitioning to another storyboard, controlling dynamic content (begin, pause, end, and set media time), (un)displaying and (un)highlighting content, and playing audio clips.
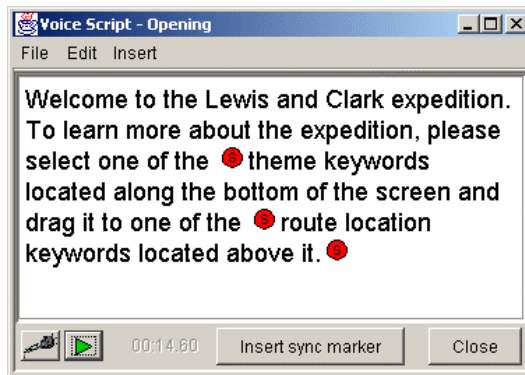
The narration editor enables a designer to develop narrative text to accompany a storyboard. The narration editor is shown in Figure 4. To gain a rough feel for how the text sounds or its length, a designer can instruct DEMAIS to read the text aloud using a text-to-speech synthesizer or record his own voice as he reads the text aloud himself. Using the narration editor, a designer can insert any number of synchronization markers into the text, enabling him to attach actions to those markers using the multi-view editor.

Figure 4. Using the narration editor, a designer can record his own voice, hear the text spoken aloud, and insert synchronization markers from which actions can be attached using the multi-view editor.

The multi-view editor enables a designer to attach actions to a narration's synchronization markers or to sketch behavior among content that could not be defined using the storyboard editor alone; e.g., defining behavior that displays a different text object in the same spatial position on a storyboard as a user rolls the mouse over one of several images on that storyboard. The multi-view editor is shown in Figure 7.

A designer creates as many storyboards, narrations, and multi-views as desired, and manages that content using the content manager shown in the lower right of Figure 7. The content manager enables a designer to cut, copy, and paste a storyboard, narration, or multi-view, and enables a designer to quickly switch among that content for editing.

6.2   Using the Tool Components to Design an Interactive Experience

Suppose a designer is challenged with the design task of designing an interactive experience for the famous U.S. expedition led by Lewis and Clark in the early 1800s [14]. As part of designing that interactive experience, the designer wants to explore an innovative navigation concept based on common themes occurring at different geographic locations along the expedition route. The navigation concept allows a user to drag a theme keyword such as "hardships" and drop it on a route location such as "lower Missouri." In response, the application jumps to the content section corresponding to the intersection of that theme keyword and route location; e.g., to the hardships incurred at the lower Missouri river. Using DEMAIS to sketch this concept is shown in Figure 5.

To build the navigation concept shown in Figure 5, the designer sketches the theme and route location keywords and a bounding rectangle around each of them. Next, the designer sketches a series of ink strokes among the theme keywords and route locations, just enough to demonstrate the navigation concept. Because the ink strokes connect recognized objects (the rectangles), DEMAIS interprets them as behavioral ink strokes and assigns a default source event and destination action to each of them. In Figure 5, the default source events of "drag and drop" were the desired events, but the designer changed the default actions of "display" to "navigate" by tapping on the navigate icon in the visual language icon panel and then tapping on the icon to replace. When a navigate icon is placed, a dialog appears asking the designer to select the destination storyboard.

To experience the navigation concept sketched in Figure 5, a designer selects the "play" button shown in the lower left corner, causing DEMAIS to operationalize the behavioral ink strokes sketched on the storyboard. Once operationalized, a designer can interact with the sketch, meaning that he can directly experience dragging and dropping a theme keyword to a route location as well as navigating to the destination storyboard. Figure 6 shows the designer interacting with the operationalized sketch. To return to edit mode, the designer selects the "stop" button shown in the lower left corner of Figure 6.
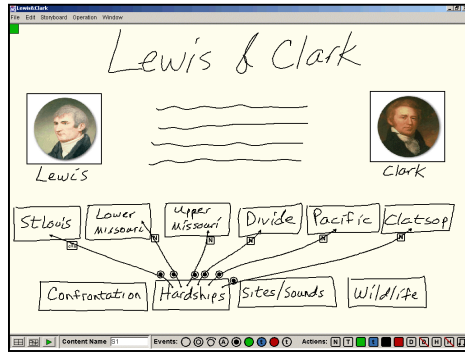
Figure 5. The designer is using the storyboard editor to explore a navigation concept based on the intersection of common themes and route locations for the Lewis and Clark experience. When a user drags the theme keyword "hardships" and drops it on a route location, the application jumps to the corresponding section.
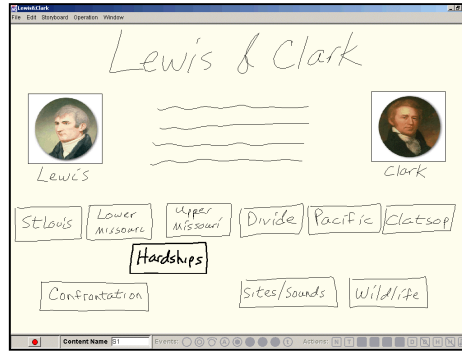

Figure 6. The designer has operationalized the navigation concept sketched in Figure 5. The behavioral ink strokes specifying the behavior are removed from view and the sketch becomes interactive. Above, the designer is experiencing how the navigation concept feels by dragging the theme keyword "hardships" to one of the route locations.
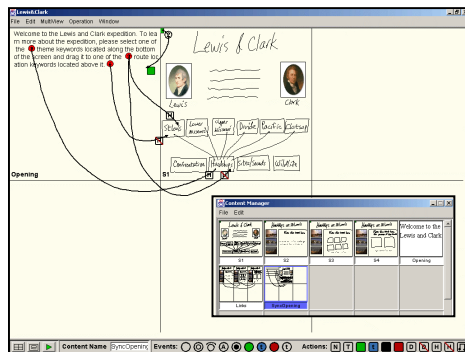

Figure 7. The multi-view editor and content manager (lower right). The designer is using the multi-view editor to synchronize the highlighting of the theme keywords and route locations on the storyboard as they are being referenced in the narrative text. To start the narration when the storyboard is displayed, the designer sketches an ink stroke from the storyboard's start symbol (upper left of the storyboard) to any location in the narration.
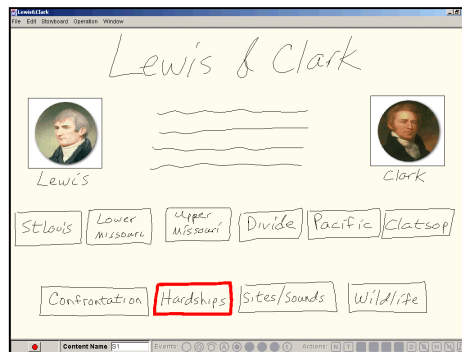

Figure 8. After sketching the behavior in Figure 7, the designer operationalizes the sketch. The storyboard is displayed, a text-to-speech synthesizer begins reading the text aloud, and the specified keywords are highlighted and unhighlighted as the synchronization markers are reached in the text. A highlighted object is drawn with a thicker, red border as shown above for the "hardships" theme keyword.

After interacting with the navigation concept, the designer decides that a voice narration explaining it to an end user is needed. As the designer develops the narrative text, he also wants to explore synchronizing the highlighting of the theme keywords and route locations on the storyboard as they are being referenced in the text. To do this, the designer creates a new multi-view and then drags the narration and storyboard from the content manager and drops them into that multi-view. In the multi-view, the designer sketches ink strokes from the synchronization markers in the narrative text to the appropriate objects on the storyboard, just enough to demonstrate the idea. To start the narration, the designer sketches an ink stroke from the storyboard's start symbol to any location in the narration. The resulting multi-view as well as the content manager window, which also shows some additional content and behavior that the designer is exploring, are shown in Figure 7. When the design is operationalized, the storyboard is displayed, a text-to-speech synthesizer begins reading the narrative text aloud, and the specified keywords are highlighted and unhighlighted as the synchronization markers are reached in the text. Figure 8 depicts the synchronized highlighting of the theme keyword "hardships" as the instructional text is being read aloud.

A designer only needs to sketch a behavioral design idea to the point at which she answers her own design questions or to the point at which that design idea can be effectively communicated to or discussed with the client or team members. Thus, DEMAIS is not a traditional prototyping tool; rather, it is an experience-based brainstorming tool for the behavioral dimensions of the multimedia design space.

7   Status and Future Work

The components of DEMAIS discussed in this paper have been implemented and the software can be downloaded from *http://www.cs.umn.edu/~bailey/demais*. As further extensions to DEMAIS, we are currently investigating:

- *An "export to SMIL [24]" function*. As a design idea solidifies and the design process iterates forward, a designer needs to create a higher-fidelity representation. By exporting the current design to SMIL, a designer can continue building a higher-fidelity prototype without having to re-implement the currently designed behavior.
- *Layer support in the storyboard editor*. Layers would enable a designer to incrementally sketch both content and behavior and focus on a specific aspect of a sketch in the context of its entirety. Layers have proven invaluable in the graphic design community and should prove to be a valuable extension to DEMAIS as well.

In addition to extending our tool, we are currently conducting a formal design study comparing the use of DEMAIS against other design tools such as pencil and paper and Authorware in the design process.

8   Conclusion

A multimedia designer has a strong desire to create innovative behavior for an application, but struggles to rapidly explore and effectively communicate that behavior early in the design process. Using a low-fidelity mechanism such as a storyboard walkthrough to simulate a behavioral design idea is often ineffective, as it is difficult to gauge from the simulation how that behavioral idea will actually feel for an end user.

A more effective mechanism for exploring and communicating a behavioral design idea is enabling a designer to *directly experience* that behavioral idea. Although creating a prototype early in the design process enables a designer to directly experience a behavioral idea, it costs too much in terms of time, money, and effort, and slows the early design process just when it needs to be rapid.

To provide an effective and affordable mechanism for directly experiencing a behavioral design idea early in the design process, we have developed an interactive multimedia storyboard tool called DEMAIS. DEMAIS operationalizes the behavior sketched and annotated on a set of storyboards, producing a working example with little additional effort required from a designer. Thus, DEMAIS combines the ease and naturalness of sketching and annotating behavior on paper-based storyboards with the communicative power of experiencing that behavior afforded by a prototype.

With the ability to rapidly create a working example early in the design process, we believe that a multimedia designer can more effectively explore, compare, and communicate behavioral design ideas, resulting in a more engaging, compelling, and entertaining multimedia application.

9   Acknowledgments

10 References

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