The Development of Mr. Potato Head, A Gesture-Based Game for the Shared Reality Environment

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ABSTRACT
Mr. Potato Head is a gesture based game developed for the Shared Reality Environment (SRE). The development of the system is motivated by the need to understand the interaction between children and computers. This is accomplished through an iterative design process as well as early focus on intended user population.

Keywords
Human-computer interaction, human interface design, gesture interface, design process, user testing, computer game, Mr. Potato Head, children, drag and drop, body tracking, shared reality environment.

INTRODUCTION
Designing computer games for young children requires careful attention to the complexity of the human computer interactions. Using devices such as mouse and keyboards adds cognitive load to the children interacting with computers. The problem is to design a game that has enough substance to keep the children interested and yet have a gentle learning curve.

We have iteratively developed Mr. Potato Head, a game that uses projection to display data on large screens and supports gesture based interactions. At the start, we defined the game's intended functionality and usage scenarios. We then looked at existing systems and established usability evaluation criterion.

We then made a paper prototype and tested it on young children. Based on user feedback, we built a flash prototype, which was evaluated by our pears who took empirical measurements. An alpha and a beta versions were then created, which iteratively incorporated more and more features.

By focusing on users and tasks early on, taking empirical measurements and following an iterative design methodology, we were able to achieve our design goals and make our system more usable.

PROJECT DEFINITION
The first step in the design process was properly defining the project. The purpose of the project definition is to properly define a project plan as well as the development of evaluation criteria that will be used to guide our decisions. As described by Gould in [1], the importance of an early focus on the intended user population and tasks were kept in mind. In what follows we define the gesture interface, usage scenario, evaluation criteria, and pros and cons of this system over others.

The Gesture Interface
What differentiates the system developed with other similar products is its gesture interface. Rather than using the conventional input tools such as mouse and keyboard, a set of simple gestures provide input to the system. The main gestures are described below:

- To activate a button or to select an object to be moved, extend the arm completely in the direction of the object or button.
- To grab a selected object, retract your arm.
- To move a grabbed object, move your arm partially extended.
- To release a grabbed object, re-extend the arm pointing at the desired location.

Figure 1. Arm gestures. The left picture shows a retracted arm and the right one an extended arm.

Usage Scenario
Sarah, 5 years old, loves to play with the traditional Mr. Potato Head. She enters the SRE and discovers Mr. Potato's head and the facial features scattered around while the animated potato helper runs across the screen saying " if you need any help point towards me!". All excited, she decides to discover the game instead of going through a tutorial. Thus, she starts pointing at facial features and notices that red rectangles keep appearing around the

features she is currently pointing at (selection feedback). She realizes that as long as she points at a feature and doesn't retract her arm, the feature will always be surrounded by the red rectangle.

Eventually, she retracts her arm and a shadow appears behind the facial feature she was pointing at. She moves her arm and notices that the feature she "grabbed" is following the movement of her arm. Happy, she moves the object around and eventually discovers that extending her arm "drops" the facial feature.

After familiarizing herself with selecting, dragging and dropping the facial features, she makes different configurations on Mr. Potato's head. Eventually, she realizes the presence of an icon with a drawing of a camera on it. Having been introduced to cameras before, she points at it and a clicking sound is heard. Soon after, the current configuration of Mr. Potato's head appears, as a snapshot, in a previously empty region of the environment.

Curious, she points towards the picture immediately discovers the presence of garbage (hidden when there are no pictures) can whose lid slightly opens up every time she points at a picture. Thus she decides to point at the trash can and notices that an animation appears showing an arm dragging a picture towards the garbage and that it disappears. Excited, she quickly understands that she can delete pictures by simply dragging them towards the garbage can.

Evaluation criteria

The evaluation criteria defined were inspired by Norman's Human-Computer Interaction (HCI) principles [3]. The principles of learnability, affordance, and feedback were chosen since they particularly apply to our system. Children do not have long attention span and need guidance. The following evaluation criteria helped us make our design decisions throughout the project:

- Learnability: Children should be able to learn it fast enough to keep them interested; this is quantitatively verified if after less than one minute of play, at least half the children understand that pointing at objects is correlated with the red highlight rectangle that appears.
- Affordance: Children understand that all the objects can be pointed at and dragged (except for the "clear potato" and "camera" buttons and the trashcan). A child who is new to the system should attempt to drag the buttons and trashcan no more than 2-3 times.
- Feedback: Children should have an unambiguous feedback whenever a facial feature is pointed at (hinting the potential of dragging it around). The clicking sound when taking a picture should emphasize that an action has occurred. Fewer than 5% of children should click the camera button multiple times due to uncertainties as to what it does and whether or not it worked.

Comparison With Existing Designs

The system is intended to have the following benefits and disadvantages over the real physical Mr. Potato Head and an online Java applet of Mr. Potato Head.

Benefits over Real Mr. Potato Head

- Child will not lose small parts.
- More functionality (saving pictures for example).
- Children are exposed to basic computer concepts (such as the garbage can metaphor) without necessarily realizing that they are interacting with a computer.

Benefits over Java Applet Mr. Potato Head

- A tutorial is provided that explains how to use the game.
- Child doesn't need to learn how to use the internet nor the computer in order to be able to play the game.
- No need to learn how to use the mouse in order to play the game
- Once again, more functionality.

Disadvantages over Real Mr. Potato Head

- Possible technological difficulties adapting trackers to children. This is not an HCI issue per se, but it's still a disadvantage if calibration is tedious.
- Currently much more expensive.
- Absence of haptics (tactile) in comparison with manipulation of the real potato head.

Disadvantages over Java Applet Mr. Potato Head

- Currently more expensive.
- Not accessible from anywhere (over the internet).

INITIAL PROTOTYPE AND EVALUATION PLAN

In order to save time by identifying design problems early on, paper prototyping was performed. This method is useful since early user feedback can be obtained before any programming is done [4]. The paper prototype helped us identify critical problems early on by testing it with three children aged 4-6. One main issue that had been overlooked thus far was the fact that most children in our target age range have very limited or no reading skills. Identifying this issue early in the design process allowed us to adapt our system before a software prototype was built.

The Prototype

After receiving feedback from our paper prototype, a Macromedia Flash prototype was designed in which a portion of the functionality was implemented. The system was designed with the goal that enough functionality would be present such that the system could be properly evaluated.

The prototype allowed users to drag desired facial features to the potato head. A clear button allowed users to return all the facial features to the selection screen.

It is important to note that a major deficiency of this prototype is that it does not support gestures. It is operated using a mouse, and as such it is difficult to evaluate whether the gestures defined are appropriate.

The Evaluation Plan

An evaluation plan was produced to allow the system to be evaluated; this includes three different sections:

Laboratory Experiment

This part of the evaluation plan involved performing a series of tasks with the system. The time the user takes to perform the task is measured and the number of errors performed while attempting to perform the task is recorded.

Cognitive Walkthrough

A cognitive walkthrough was performed in which users are asked to perform a set of tasks and for each task three questions must be answered:

- What actions does the user need to perform?
- How does the interface support these actions?
- What assumptions are made about the user's knowledge and background related to the system?

Heuristic Evaluation

A heuristic evaluation plan was prepared based on Nielson's Ten Usability Heuristics [2]. From the ten heuristics, "Visibility of system status", "Consistency and standards", "Error prevention", and "Aesthetic and minimalist design" were considered.

EVALUATION RESULTS AND RECOMMENDATIONS

Kidz Corner carefully evaluated the prototype based on the evaluation plan mentioned above. Although they were unable to evaluate unsupported features in the prototype, they provided insightful comments. One of the biggest problems identified revolved around our clear button; its function was not easily understood by children. The function of the garbage can was also rather vague; it was not clear to children whether its purpose was to delete facial features or saved images. The buttons for the camera and clear buttons were red and green, which caused mapping confusion related to "stop" and "go".

DEVELOPMENT OF AN ALPHA SYSTEM

Based on the feedback provided by Kidz Corner as well as TA's, an Alpha system was developed. The main improvements involve changes to the buttons as well as changes to the garbage can.

- The button colors were changed to more neutral colors since the red and green buttons caused mapping confusion related to their "stop" and "go" meanings.
- The clear button's icon was changed; now showing a Potato Head with a few facial features at its feet.
- The garbage can icon was changed and an animation was added; when a saved image is grabbed the garbage can's lid gradually opens up as the picture is moved closer.

Figure 2. Comparison Table between flash prototype and Alpha System. The left column represents the Flash prototype elements and the second the respective Alpha System elements.

Although the functions themselves were not implemented, two features were added: an interactive tutorial and a potato template game. The icons for each of these functions were displayed in order to test whether their function was clear, even if the function itself was not implemented. The interactive tutorial's icon was the picture of a potato head holding a sheet of paper portraying a teacher. The potato template was simply a snapshot of a potato configuration for children to follow.

Figure 3. The Alpha System Interface.

A user manual was provided with the release of the Alpha system. The manual explains which gestures are used to

perform each desired action, as well as a detailed description of each function supported by the system.

DEVELOPMENT OF A BETA SYSTEM

The feedback provided concerning the changes made for the Alpha system indicated that improvements made to the garbage can greatly increased its usability. Although changes to the clear button helped provide more information about its use, it was still confusing to many users. The biggest problem with the Alpha system involved the added potato helper and the template potato. Users were confused and had no idea what their purpose was. It was also noted by a child that the potato helper icon seems to be holding a "garbage bag"; this created a link between the icon of the potato helper and the garbage can. This is clearly not what was intended.

In the process of developing the Beta system, additional user testing was performed mainly with the purpose of testing new animations. An animation was added to the clear button, when a user points towards the button with an un-extended arm the animation is displayed. This animation shows a shrunk version of the main work area and feature selection screen with facial features being removed from the potato. A second animation was added to the garbage can, it is displayed when a user erroneously points at the garbage can. The animation consists of showing how it is used, by showing a saved picture being dragged to the garbage can to be deleted. Testing indicated that both animations made the function of the clear button and the trash can more easily understood; the animations allow the conceptual model to be properly grasped.

In addition to the new animations, additional functionality was added to the system. The Beta includes the functions of the Alpha as well as fully functional saving and loading of images. Rectangles are used to provide feedback about highlighted features. Audio feedback has been added to give information about incorrectly performed actions to help users understand what they did wrong.

The potato helper's character was replaced by Mr. Potato with a question mark on his head. An animation was added to the helper potato that is accompanied with the audio message "If you need help, point towards me!" to let children know how to start the tutorial if they have problems. Finally, the reset and camera buttons were switched so that the functions are compounded in regions (pictures on the left, facial features on the right).

The tutorial for the system is still at a primitive stage of design. A video has been made that shows a user showing how to perform each function with the proper set of gestures. Further testing is required in order to evaluate if the explanations provided are sufficient and appropriate.

Also, it was decided to remove the template potato feature. Children did not understand what the template potato icon was for. Furthermore, when they were told what it was, children replied that they preferred creating their own designs rather than following a template. It was therefore decided to drop this feature.

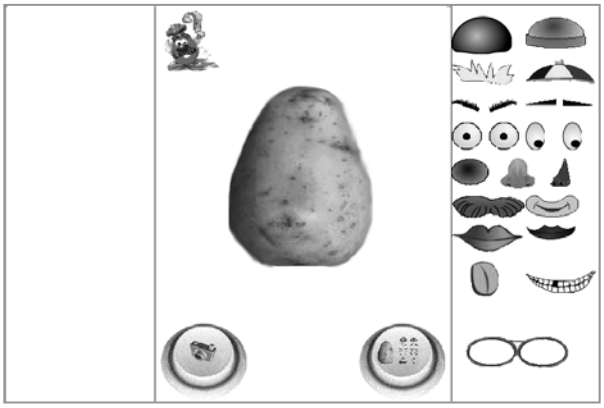

Figure 4. The Beta System Interface

It has been suggested that it may be useful to be able to open up the trashcan allowing the user to retrieve deleted images. The addition of this feature has been considered; however it would add a considerable amount of complexity to the system. It is also important to note that the system is intended to be used by children and so irreversibly losing "data" is not a crucial issue. For these reasons, this function has not been incorporated into the system.

In addition to the various improvements brought to the system, the Beta system was completely recoded in Java rather than Flash. This was necessary in order to open a User Datagram Protocol (UDP) socket to communicate with the body trackers. Also, for testing purposes, the system still supports mouse input; however it has been modified from the Alpha. In order to facilitate the mapping between the mouse interface and the gesture interface, the mouse now uses both the right and left buttons. The left mouse button corresponds to extending the arm whereas the right mouse button corresponds to retracting the arm. Moving the mouse around still corresponds to moving a partially extended arm.

In the SRE, only the x coordinate was tested. The y coordinate was fixed to a specific value. In the future, the system could be further developed to fully support the gestures.

HCI CONCEPTS

Many concepts learned in class were taken into account during the development of the Mr. Potato Head game. A brief description of how the system conforms to them is provided below.

Conceptual Model

The limited number of actions that a user can perform makes the conceptual model simple. From the user testing performed on the Alpha system, it was noticed that indeed children learned quickly that they could place facial features on the Potato's Head, take pictures and throw images in the garbage. This shows that the children are able to grasp the conceptual model; however in case some of them cannot, a tutorial was provided.

Visibility

As soon as the system is loaded, all facial features, the Potato Head, the camera button, the clear button and the potato helper are displayed. That is all elements that the user can interact with are all visible on the screen. Moreover, the Potato Helper is animated with sound, to ensure that the user will notice the Helper and know that if he needs any help he can simply point towards the helper at any time. The buttons are made larger so that the user can see them immediately as soon as the system is loaded. Moreover, the garbage only appears once a picture is taken. So the visibility of the system is dependent on its state. Finally, the different elements are grouped using the frames in order to allow the user to find any object he is looking for without getting confused by the presence of many items.

Feedback

Our system provides the user with feedback corresponding to his/her actions. When an object (picture or facial features) is selected a rectangle appears around it. The colors of the rectangles depend on the type of the object being selected. Blue is used for pictures and red for features. In addition, the user knows when an element is actually "grabbed" since at that moment a shadow appears behind it. Also, the user can quickly notice that an object is "dropped" since at that point the shadow will disappear. Finally, when a button is "activated" a corresponding sound is emitted. However, when an incorrect action is performed such as dropping a facial feature over a button or in the garbage an error message is emitted, explaining what is wrong. These sounds were carefully designed since they are meant for children. That is, short sounds were used to give feedback on correct actions while longer error messages were used for incorrect ones.

Help User Recognize, diagnose and recover from errors

Users are informed of their mistakes with the use of both sound and visual cues. Indeed, if as user tries to drag an object over an area where it cannot be dropped, a red cross appears over the element. In addition, if it is still dropped in that area, it will be automatically moved back to its previous location and an auditory error message is emitted. Finally, if the user tries to point at the garbage instead of dragging a picture towards it an animation will appear explaining the reason why nothing is happening and how to actually perform the correct action.

Constraints

As mentioned above, objects which are dropped in an "illegal" area are automatically moved back to their previous location. This prevents the user from trying to delete any object which is not a picture. It constitutes a constraint, as in, it prevents users to place elements in areas which might cause some problems in the system. Finally, another constraint would be the disappearing of the garbage once there are no pictures to delete anymore.

Help and Documentation

A tutorial is provided with the Potato Head's game which teaches target users how to use the system. Besides explaining the different gestures the users have to do in order to select, grab and drag objects, the tutorial also demonstrates how to clear the main work area as well as how to take pictures (to save) the current design. In addition it also describes how to use the garbage can in order to delete any unwanted pictures. It also includes a brief summary of how to reload pictures into the main work area for further editing. Finally, while in the system itself, some animations were implemented to provide the users with easily accessible documentation. That is, there are three animations which explain how to use the garbage can (drag pictures towards it) and what the functionality of the clear button is.

TECHNIQUES

Mr. Potato Head Team used various techniques in order to ensure the implementation of a simple and usable system. The techniques employed are described below.

Iterative design

The design of the Mr. Potato Head system was an iterative process. In fact, to avoid having to perform many changes to the system, late in the design process, a paper mock-up was built in order to discover early on the possible problems that would have been encountered otherwise. Once the results were compiled and reviewed, the implementation of the system was launched. Various system versions were developed, tested and redesigned according to the feedback obtained from the evaluators. Consequently, the system continuously evolved from start to end of the design process. It now incorporates more functionality, a more usable interface and more help and documentation.

User-centered Design

Users (children aged 4 to 6 years old) have been included in the design from the very beginning of the development of the system. Indeed, the paper mock-up of the system allowed the team to gain early insight on the knowledge and understanding of young children. Observations about the capabilities and interests were made and immediately taken into account. Each and every modification to the system was made in order to make it more usable for the users. In fact, the system was built in a way which allows the user to learn how to use it, all on his/her own. Finally a user was filmed while playing with the alpha version of the

system. The members of the team then carefully analyzed the film and observed the different problems the user was having while trying to interact with the system. Modifications were made to the game accordingly.

CONCLUSION

aged between 4 and 6 years old. The key to develop such a system is applying an iterative and user centered process. The feedback provided by user testing was crucial to the success of the design. By involving the user from the very beginning, the team was able to focus and work on important issues early on.

The biggest challenge was to ensure that children would be able to interact with the system properly. Indeed, children are very unpredictable and have developed different skills depending on their background. In addition, some of the children have never been introduced to the concept of Mr. Potato Head and might not be able to understand the concept of the game without guidance. Focus on the user allowed the team to think about these issues early in the design process.

Further improvements can be made to the system by performing additional design iterations. In addition, perfecting the gesture interface would allow to envision the system in all its glory and to truly display the advantages that it provides compared to the real and the Java applet Potato Head game.

The main goal of Mr. Potato Head team was to design a software application complying with the HCI principles mentioned above. The system developed needed to be interactive and fun, but most importantly usable for children

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