Strawbies: Explorations in Tangible Programming

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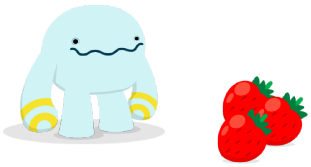
ABSTRACT
In this demo we present Strawbies, a real-time tangible programming game designed for children ages 5 to 10. Strawbies is played by constructing physical programs out of wooden tiles in front of an iPad. This interaction is made possible with the use of an Osmo play system that includes a mirror to reflect images in front of the iPad through the front-facing camera. We combined this system with the TopCodes computer vision library for fast and reliable image recognition. Here we describe a set of principles that guided our iterative design process along with an overview of testing sessions with children that informed our most recent instantiation of Strawbies.

Categories and Subject Descriptors
H.5.m [**Information interfaces and presentation (e.g., HCI)**]: Miscellaneous.

Keywords
Children; tangibles; games; strawberries.

1. INTRODUCTION
In this demo we present Strawbies, a tangible programming game designed for children ages 5 to 10. Strawbies is an iPad app that features Awbie, a character that children guide on a quest for strawberries through a virtual world using wooden programming tiles (Figures 1, 2, 3). Our system combines the TopCode computer vision library [TOPCODES] with the Osmo play system [OSMO] to allow for real-time recognition of programs that children construct on a flat surface in front of the iPad (Figure 1). This results in an inexpensive, engaging, and portable tangible programming environment. Our design process has involved three major revisions of the game that we tested with children, parents, and teachers (see Figure 4).



2. DESIGN PRINCIPLES
Our design builds on prior work in tangible interaction and children's programming environments and was guided by the following eight principles:

1. Inviting: Through the use of tangible programming tiles, we hoped to create an inviting experience that would draw children into collaborative play. The use of tangibles increases the visibility of game play, allowing it to move beyond the screen and spill out into the real world. In our testing sessions, children would often notice the game from across the room.

2. Playful and Open-Ended: In the spirit of many children's programming environments [PAPERT, ETC], we wanted to support children's open-ended exploration. This led us, over time, to an open-world style of game in which Awbie is free to roam around an infinite, randomly generated landscape. While the game is loosely structured around the task of guiding Awbie to eat and grow straberries, children are free to playfully explore the world in any way they see fit.

3. Simple+Complex: As with prior work on the development of programming environments for informal learning settings [Horn,

Figure 1. Children playing with Strawbies using tangible tiles, an iPad, and the Osmo attachment.

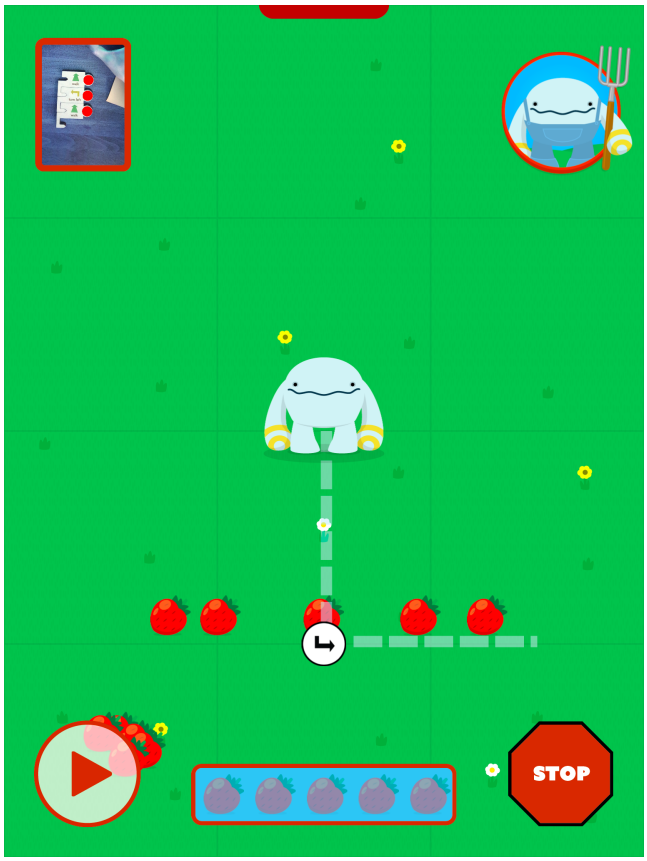


Figure 2. Screen shot of the iPad app. The game shows an image from the front camera to help reinforce the link between the tangible programming tiles and Awbie's movement in the world (top left). We use arrows and icons to preview what will happen programs are played.

Horn, CMU], we wanted to create a system that was simple enough for children as young as five years old to figure out on their own with little or no instruction. However, we had to balance this goal of simplicity against the ability to create relatively sophisticated programs that would lead to complex behavioral outcomes for Awbie.

4. Fluid and Responsive: Tangible programming systems that rely on computer vision have typically had to make tradeoffs between inexpensive materials, portability, and real-time interaction [Horn]. Achieving continuous recognition of tiles usually requires an overhead camera fixture or an interactive surface with built-in camera hardware. It is possible to instead use a mobile device like an iPad, but this requires a point-and-shoot style of interaction (e.g. [Horn'13]). However, with the Osmo's use of a mirror in front of the camera, it is possible to create fluid, real-time interaction with a mobile device and low-cost tangible materials.

5. Developmentally Appropriate: We wanted to ensure that the content of our game was appropriate four our target audience and that the game play was aligned with children's cognitive, perseptual-motor, and social ability. To ensure that we achieved this, we conducted multiple rounds of testing with children in our target age range.

6. Pedagogically Aligned: One of the greatest challenges facing the adoption of developmenally appropriate technology in classrooms is that teachers must feel comfortable and confident with the materials [CUBAN]. This includes making sure that technology aligns with the pedagogical philosophy of early childhood educators, a philosophy that emphasizes rich sensory-motor experiences, open-ended exploration, and social interaction. We see the use of tangible technology as an excellent way to introduce computational thinking activities in a way that evokes familiar cultural forms of teaching and learning [Horn].

7. Social: Along the lines of the previous design principles, we sought to design an activity that was inherently social in nature and that would invite multiple children into the game, allow them to easily distribute their activity in collaborative play, and create space for multiple hands and bodies.

8. Adaptable: The difference in ability of a five-year-old and a ten-year-old child can be dramatic. In developing the game, we sought to create an activity that could grow with the child, perhaps with the proximal assistance of an adult or older child. For example, for pre-literate children, it might be necessary to read text out loud to help children interpret meaning and understand the graphical elements of the blocks. Or, teachers might choose to remove some of the blocks (such as the event triggers) from the activity until a child has mastered the more basic concepts. This is one example of the flexibility that tangibles afford—no customization of the software is necessary to instantly adapt to the abilities of different children.

3. RELATED WORK

Our project builds on a long and rapidly growing tradition of programming environments for young children [Papert, diSessa, Weintrop, ScratchJR, Montemayor, Wyeth, Dr.Wagon, Tern, Stickers, Scratch, Logo] (see also [McNerney] for an excellent account of older work dating back to the 1970s). There is also growing momentum around the idea of supporting computational literacy activities throughout K-12 education, starting at the earliest grade levels. Our project contributes to this space by improving the flexibility, portability, and practicality of tangible programming for young children.

4. DESIGN ITERATIONS

Our design process involved several major revisions in which we explored different approaches for the iPad app and the tangible programming tiles. For the programming tiles, we wanted to make sure that they were easy to assemble and disassemble while allowing for connected programs to be dragged around the table without falling apart. We included parameters, loops, and if/then logic. The blocks were split into several categories: verbs, adverbs and units of measurement. Verbs slide in and out of other verbs conveniently, while units and adverbs attach to verbs like puzzle pieces. Each string of verbs could start with an `Always` block (for looping behavior) or a `When` block (for if/then logic). Due to the limited field of vision of the Osmo, we chose to use event-driven logic over sequential logic.

Version 1: Puzzle Based

Our first game iteration consisted of a series of puzzles, much like code.org's Learn Programming series. From testing, we found that our players were easily frustrated by the game—especially the

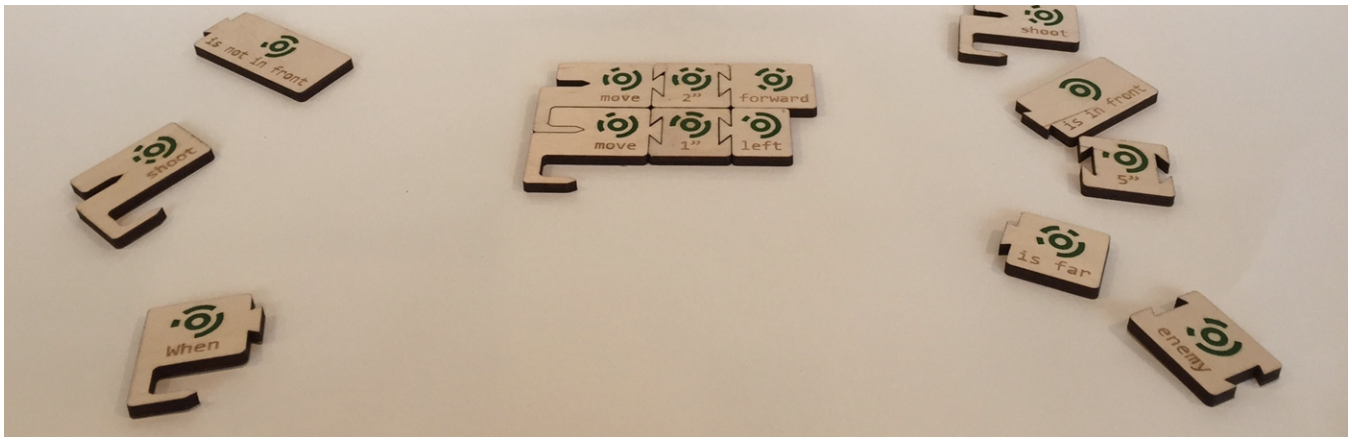


Figure 3. Collection of programming tiles available to guide the character in search of stawberries.

lower end of our target age range. Puzzles had only two or three possible solutions, and failure meant that players had to restart the puzzle. We felt that the interaction opened up by the Osmo and tangible pieces could be much more playful and open-ended.

Our screen layout was also influenced by Scratch Jr. and other tablet coding games that do not use tangible pieces. Half of the screen was, therefore, dedicated to showing what the iPad was reading (Figure 4, left). This was unnecessary, as the physical code blocks in front of the iPad is an extension of the UI.

Version 2: Open World Environment

Realizing that the physical representation of programming tiles did not require screen real estate opened possibilities for redesign. Responding to user testing, we created an open world game in which the goal was to harvest "Strawbies". Because we wanted to create a fluid and responsive game that reacted in real time to kids' programs, every block that was recognized by the system would be immediately added to a pool of actions that the avatar could perform. The game would randomly chose from all tiles in front of the iPad and perform that action.

The structure of the game was provided by obstacles: water, trees, and bats. Trees obstruct movement, while contact with water or bats caused the game to end. Players could add events triggered by obstacles ("When water is in front, turn 90 degrees right and walk"). This version was better received by players, but there were a few issues. Blocks had too many qualifiers; a line of code could require up to three different tiles. The game was also too challenging for children and even for adults. Furthermore, collecting strawberries did not appear motivating enough to engage players in deeper explorations of programming concepts.

Version 3: Refining the Open World Game

In this version, we kept the open world concept and made additional refinements to improve fun and playability. We started by simplifying the action blocks and removing required qualifiers. Player could instead attach numbers to verbs to increase the number of times an action is performed. We also added room for graphical symbols on each block to increase the accessibility for young children. In this version, we also made looping an explicit tile that had to be used to cause actions to be repeated more than once. To make the game less frustrating and more fun we added three special action blocks: rainbow, tornado and flashlight. The rainbow flies the avatar to a different place in the world, the tornado consumes all the strawberries in a short radius, and the flashlight scares away rats that are trying to steal the Awbie's strawberries. To give users an idea of progression and ownership, we added a separate farm game-within-a-game. As players collect strawberries, they can start to grow fruit bearing plants in a garden. A separate screen shows garden rows that slowly fill with Strawbie plants that Awbie can harvest.

5. EVALUATION

We brought the game for six play sessions at two preK-6 schools. We tested the game in two environments: a closed off space with two children at a time, and an open environment with many kids coming and going. Most play testers wanted to play more when asked told that their time was up. Our sessions were divided into 20-30 minute slots. The idea of growing a garden of strawberry plants and and tapping on increasingly more strawberries seemed motivating for the children.

Collaborative phrases such as "can you pass me this block", "don't do that, I want to do this", "we need to bring him down, do you see anything" were common as teams of play testers work towards a common goal. Physical collaboration was also common: for example, holding back another's hand or moving an undesired piece outside of the camera range.

When the play sessions were in open spaces, there were two occurrences of children coming up and asking what the blocks were. Once the children who came up started to play, other children would join in. When we tested in the open area, a group of five students eventually came to form around the iPad. Even though there was five students around one iPad, none of the children seemed bored. There were always pieces in front of them that they could play with, or slide in and out of the iPad's field of view.

Differen children interacted with the blocks in different ways. One boy in Grade 3 turned the block to face the iPad screen, so that the word "Walk" was facing the avatar on screen, and not himself. Another child thought that tapping on the block would send a signal to the iPad. However, with some hints (which could be replaced by tutorials), the children understood the how the tangible blocks worked without any more hints. Young children (ages 4-5) were able to remember the names of blocks such as rainbow and walk, despite not being able to read them initially.

A common behavior was to use only single actions. This was

Figure 4. We have developed three major revisions of the game that we have tested with children, parents, teachers.

observed for young as well as older children (ages 4-10). While we do not believe that this is an undesirable behavior as the children are learning the game and connecting blocks to actions, we are experimenting with ways for the next iteration to eventually encourage the players to use longer blocks and plan more strategically.

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