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Abstract

Pluff is an experiment in using e-textile technology to develop tactile interface devices for video games. The prototype consists of a stuffed animal embedded with sensors and wireless communication that functions as a game controller, and a corresponding game that is played in Flash. Pluff seeks to increase the sophistication of e-textile applications and methods. At the same time, the combination of onscreen content and physical interface create an emotionally engaging experience for the user.
Introduction

The primary research agenda of the Pluff project has been to create intersections between recent work in the fields of electronic textiles and tangible user interface devices for video games and other interactive applications. The development of simple, inexpensive e-textile technology means that game controllers and other human-to-computer devices need not be made of rigid plastic or metal. An entirely new realm of user experiences is available, especially experiences that emphasize the tactile and physical aspects of interacting with a digital system. Pluff presents a proof of concept of one such interaction possibility.

While much work has been done with electronic textiles in terms of the creation of new materials, techniques, and ready-made sensors with the goal of keeping devices as “soft” as possible, this work tends to focus on the creation of wearable devices (Buechley). Some non-wearable pieces exist, but these largely are designed for aesthetic, and do not involve much tactile interaction (Stern).

In contrast, tangible interface devices for video games are often designed to be manipulated by a user’s hands, with care taken to ensure that they provide a satisfying haptic experience. These devices encourage touch and gestures as the primary mode of input, seeking to translate user behavior into onscreen results in an intuitive fashion. The Nintendo Wii is a recent example of this approach to interface device design, as are the controllers for musical game Rock Band. However, such devices tend to use more traditional materials in their construction. While motion sensing and vibration feedback do provide a more tactile experience, these interface devices conform to traditional game controller designs in their uses of hard plastic enclosures and plastic buttons. Such devices also encourage the user to approach them as objects; they take the shape and function of familiar real-world items like guitars, drums, or tennis rackets (“What is Wii?”) (Goldstein et al.).
Pluff, then, seeks to merge the goals of these two fields by creating a tangible interface device that takes advantage of electronic textile techniques to provide a more tactiley engaging experience. The end result of the project is a furry stuffed animal, embedded with sensors, that is used to interact with a Flash video game. Traditional electronics tend to be rigid and draw attention to themselves in the context of a plush item, so Pluff’s interface device takes advantage of e-textile techniques to retain many of the characteristics of a traditional stuffed animal. The device is furry and soft, can be squeezed and deformed to an extreme degree, and has few (if any) easily detectable electronic pieces. It also possesses a face and a direct on-screen counterpart. Instead of treating this device as an object, Pluff encourages the user to engage with the device as a character to relate to.

Between its furry, huggable form and engaging onscreen content, Pluff should facilitate an emotional connection between the user and the Pluff character in a way that a traditional game controller could not. At the same time, it should push e-textiles out of their current simple applications and into more complex electronic applications.

**Related Work and Influences**

**Electronic Textiles:** The use of conductive threads, fabrics, and other textile-related items to build functional “soft” circuits and interface devices has increased in popularity and sophistication in recent years, particularly with the work done by Leah Buechley and the rest of the Craft Technology Group at the University of Colorado, Boulder (Buechley). E-textile applications tend to rely on simple interactions; one method of input (a light sensor, for instance) affecting one mode of output (a piezo speaker or LED array).

**Swamped!** A stuffed animal loaded with motion and orientation sensors is used as the interface to control a 3D character in a video game world. The movements of the physical toy directly dictate the
motions of its onscreen counterpart. For instance, when the user flaps the toy’s wings, the onscreen bird will fly (Johnson et al.).

**Action!Doll**: A cloth doll with potentiometers at its joints is used to control an onscreen character in a Flash video game. The user must pose the doll, copying and executing a series of “dance moves.” (Choi)

**The Rowan**: A literary work in which a child is gifted with a "pukha", a sensor-laden stuffed animal notable for its sophisticated capability as an interface as well as the relative invisibility of its technology. In particular, the toy "responded with its soothing, rumbling purr when the little girl became restless or distressed."(McCaffrey 22)

**Nintendogs**: A commercial video game for the Nintendo DS in which the player cares for a digital “pet”, including giving it treats, petting it, and teaching it tricks. ("Nintendogs")

**Webkinz**: A commercially available line of stuffed animals that include ID numbers for use with an online game and activity service. The user "adopts" a digital pet, a doppleganger for their stuffed animal; the user buys food, clothes, and other accessories for their pet with digital currency earned by playing minigames and participating in Webkinz community activities. Though the stuffed animal and digital pet are linked symbolically, there is no direct connection between toy and code. ("Webkinz")

**Ugobe’s Pleo**: A commercially available toy robotic dinosaur, laden with motion and touch sensors as well as a camera-based vision system. The user cares for Pleo as a pet; Pleo can be petted and learn tricks, and has a limited range of autonomous behaviors (such as exploring the surrounding
environment). Pleo is a stand-alone device, having no PC-based component that is integral to the experience ("What is Pleo?").

**Project Description and User Experience**

*Pluff* consists of two major components: a sensor-laden stuffed animal, or Plush Interface Device (PID), and a Flash game running on a PC. The user plays the game by manipulating the PID to affect the moods and behavior of an onscreen character whose appearance closely mimics that of the PID. Petting or hugging the PID will improve the mood of the onscreen character, while dropping or shaking will result in a negative reaction. The user can also coax the onscreen character into performing "tricks" by executing a particular sequence of actions with the PID. The game consists of two "modes": an open environment where the player can experiment with the PID to find combinations of actions to produce interesting reactions, and a guided "obedience school" mode where the player is led through the process of training the onscreen character to perform tricks.

**Plush Interface Device**

The plush interface device is a round, furry stuffed animal outfitted with touch and motion sensors, wireless communication, and a microcontroller. Specifically, the device contains the following:

- **Lilypad Arduino**: a sewable microcontroller which handles gathering and processing of sensor data, as well as transmitting roughly filtered data to the PC via a serial port
- **Bluetooth modem**: allows wireless communication of serial data from the PID to the PC
- **Flex sensors**: 4 flex sensors, consisting of flexible material and a band of resistive cells, detect petting, squeezing, and other deforming pressures along the body of the PID
- **3-axis accelerometer**: programmed to look for sharp acceleration/deceleration
- **Vibe motor**: allows the PID to "purr"
• LiPower power supply: ready-made 5v power supply with on/off switch, connected to a rechargeable lithium-polymer battery

Figure 1: The “Plush Interface Device” (PID)  Figure 2: Exterior of PID with fur shell removed

Figure 3: Fabric-based connections to power and ground  Figure 4: Central hardware assembly

Because the PID is intended to provide a soft/furry tactile experience, great care has been taken to keep the user’s ability to feel the PID’s hardware to a minimum. Hardware components are small and lightweight, generally no thicker than ¼”. Wherever possible, circuits in the PID are constructed using conductive fabric, conductive thread, and small metal snaps, as sewn circuits integrate more readily with the PID’s fabric-based structure. All hardware components are liberally padded: the
inner shell of the device is constructed of lightweight cotton muslin, to which the hardware is attached. The shell is stuffed with polyfill quilt batting, with a layer of felt insulating the larger hardware components located at the bottom of the device. This shell is then covered in a layer of thick padding, before finally being covered by the PID’s furry outer layer.

The PID looks for deformation of its surface, where lighter deformations are interpreted as petting or stroking, while extreme deformations are interpreted as unwelcome or abusive squeezing. It also notes extreme changes in acceleration, which would indicate that the device is being shaken, dropped, struck, or otherwise being handled in a violent manner. In general, it has been more efficient to test for broad categories of interaction (gentle vs. violent), rather than very specific actions like hugging. This approach gives the player a great deal of freedom in their interactions with the PID, and saves the designer from needing to program for every eventuality. However, the hardware setup of the PID could certainly be programmed for any number of specific eventualities, even so far as to adapt it for an entirely different interactive experience. The Pluff Flash game is one demonstration of the PID’s capabilities, but many others are possible given the existing system.

The PID is limited in its capacity to give the user feedback. Its sole output device is a small vibe motor which, when prompted by the PC, cycles from weak to strong vibration and back. The end result is a gentle, cycling “purr”.

As described above, the PID communicates with the PC via a Bluetooth modem. However, the connection between the microcontroller and the Flash application is not a direct one. Arduinos transmit serial data via COM ports, but the Flash environment cannot directly access hardware in this fashion (a security precaution, as Flash is primarily a web environment). Pluff takes advantage of a serial proxy (called TinkerProxy) which translates a serial port into a TCP/IP port. Flash, with its
built-in socket connection support, can then read in this spoofed network data and respond accordingly.

**Flash Application**

The PC-based component of the Pluff project is an application running in Adobe Flash CS3. The application consists of two modes: an open exploratory mode, and a goal-driven game mode. Both modes allow the user to interact with an on-screen character, a digital counterpart to the physical character represented by the PID. In addition, both modes share the same library of detectable user behaviors, as well as a common art style, narrative environment, and sound/music library.

**Exploratory Mode:** In this section of the application, the user can experiment with the PID to see what behaviors elicit responses from the onscreen character. Here, the user learns that their behavior towards the PID influences the mood of the onscreen character. Friendly behaviors, like petting and hugging, result in a happy mood, while unfriendly behaviors, like shaking or dropping, result in an unhappy and eventually distressed mood. The user can also discover and practice commands which will lead to Pluff performing tricks like rolling over or standing on his head.

**Game Mode:** In this section, the user is guided through a simulated "obedience school" course, wherein they learn to train their furry companion to execute simple tricks. In much the same vein as a real obedience course, the emphasis is more on training the "owner" than it is on training the "pet". The user is taught to manipulate the onscreen character into a positive mood, issue a command via a specific gesture (turning the PID on its head, for instance), and then respond with positive input for a trick correctly completed or negative input for an incorrect trick. When the onscreen character is rewarded for a correct trick, its mood improves; when it is not rewarded, or if the trick is unsuccessful, the character's mood is diminished. The user wins the game by successfully
demonstrating a number of these tricks, in a sequence similar to the “final exam” of an obedience school course.

Aesthetics

The visual style for the Flash application emphasizes texture, reflecting the tactile nature of the PID. Photographic images of fur, leaves, and other textures are overlaid on otherwise solidly-colored shapes, creating a collage effect. Simple hand-drawn shapes and a light, bright color palette add to the friendly, nonthreatening atmosphere of the experience.

Pluff’s character and toy design were strongly influenced by the aesthetic of Ugly Dolls and similar handmade stuffed animals. In particular, elements that Pluff adopts include unusual body forms, asymmetrical details, oversized features, and a largely unrefined feel (Uglydolls). These elements dovetail nicely with Pluff’s need for texture and a distinct look, as well as with the larger DIY philosophy at work both in these toys and in Pluff.

Pluff’s sound design relies heavily on musical instrumentation. There is a continuous bed of background music, and the onscreen character’s “voice” consists entirely of short, trilling bursts of melody played on a clarinet. Because Pluff is somewhere between an infant and an animal, the character does not possess speech, relying instead on the emotionally expressive nature of the clarinet tracks. The goal with Pluff’s sound design is to create an aural experience that both communicates necessary information (the onscreen character being distressed, for example) and complements the friendly, textured feel of the visual and tactile components of the application.
Design Methods

Design for the PID was guided in large part by periodic interaction with potential users. These users were adults; most were connected to the video game community in some fashion, whether professional developers or simply game enthusiasts. Before the actual device was constructed, initial exploration began using a stand-in stuffed animal. This investigation provided guidance regarding what users might need or want from a PID. Once sensor-laden plushes were functional, they were tested with users to gauge emotional response, ease of use, and degree of fidelity in the sensing apparatus.

Generic Stuffed Animal

Subjects were given a plush monkey to play with during the course of both everyday conversation and conversations specifically about the Pluff project. The purpose of the experiment was to observe how adults instinctively interact with stuffed animals, when given no instructions other than "here, hold this."
From this experiment, it was determined that users would require several things from a plush interface device. First, they wanted to interact with the PID as if it were an entity in its own right, rather than as an object or tool. In particular, they would treat the monkey as if it possessed awareness, refraining from hitting or otherwise mistreating it. They might speak to it, or imbue it with imaginary behavior ("he is drinking my water" or "we are hanging out"). Users demonstrated a capacity and desire for emotional connection with the stuffed animal. Across the board, demonstrations of affection were the norm; the first action taken in most cases involved some form of petting, hugging, or cuddling. Behavior changed slightly once users were informed that the stuffed animal might serve as a video game controller. They expected that a stuffed animal game controller would involve some form of puppetry of a digital character. There was a pronounced desire to imitate a 1:1 relationship between the doll's and the proposed onscreen character's movements.

**Limbs**

Initially, the PID was designed to include limbs, in keeping with a more traditional bipedal stuffed animal form. Early user testing had indicated that users desired to use the animal's limbs to affect locomotion and other movement-based behaviors in the onscreen character. Because Pluff's onscreen component is in 2D (while a user’s movement is necessarily in 3D), and because hardware for sensing the movement of joints tends to be rigid and cumbersome, a direct 1:1 relationship between the user’s manipulation of the interface device and the onscreen character’s movement was discarded in favor of the current indirect behavior manipulation model. To reduce user confusion, the interface device's limbs were removed entirely, giving the Pluff device its final distinct shape.

**Sensing Touch**

Because petting, hugging, and squeezing are physical behaviors strongly associated with stuffed animals, it was imperative that they be supported by the PID. While these behaviors could be supported by a number of technological solutions, one in particular was initially promising. Using an
embroidery machine threaded with conductive thread, it is possible to create a set of conductive pads for use with a capacitive touch sensor. It is also possible to create such pads through the use of iron-on conductive fabric. In either case, the result is unsuitable for Pluff; the sensing pads must be entirely exposed, and therefore cannot be covered by any sort of fur. This method does bear further investigation, however, as the ability to transform any fabric into a touch-sensitive surface presents interesting opportunities. Ultimately, flex sensors sewn to the inner shell of the PID proved to be the most workable solution. These sensors conform easily to the PID's rounded shape, and are sensitive enough to provide ample fidelity in sensing deformations to the PID's surface.

Flexible Hardware Design

A common tool in traditional electronics prototyping is the breadboard, a device covered in solderless contacts and containing a common ground. Electrical components can be added and removed to a circuit easily, facilitating rapid changes to a growing prototype. Unfortunately, a similar device has not been developed for use with e-textiles. A normal breadboard will not suffice, as its contacts do not accept anything other than stripped wire; conductive fabric and thread cannot connect directly. The accepted practice has been to use alligator clips connected by insulated wire; the clips can connect to a hardware component and then to whatever other component is required. This approach is serviceable when the circuit being developed is not enclosed and no parts of it are installed in the final device.

The production of the PID required the development of a fabric-based method for breadboard-like prototyping, to facilitate rapid swapping of hardware components. In particular, there needed to be a way to install sensors whose location was not likely to change (like the flex sensors in the body of the PID) and connect them to hardware that was likely to be pulled out for further development (like the Lilypad Arduino, the power supply, etc). To this end, metal snaps and insulated conductive ribbons were employed to facilitate temporary connections between hardware components. Male snaps
were attached to the tabs of the Lilypad; external components like the flex sensors were outfitted with strips of conductive fabric (insulated in cotton muslin) outfitted with female snaps. The result is a “fabric breadboard”; the developer can remove the Arduino and other key hardware at will without needing to dismantle the entire PID assembly. This technique has proved valuable in other e-textile projects as a way to do rapid prototyping; it is highly recommended in applications where some components need to be removable.

![Fabric breadboard](image1)

![Conductive ribbons with snap connections](image2)

**Figure 6: The fabric breadboard**

**Figure 7: Conductive ribbons with snap connections**

### Controller-based Feedback

Several options exist for hardware-based feedback in Pluff, but ultimately most were discarded. LED's, peltier modules, audio speakers and vibe motors all were evaluated as potential ways to add tactile and aural feedback to the PID. LED's were discarded out of hand, as they represent the synthetic and the digital, both concepts which Pluff avoids. Peltier modules provide the interesting possibility of temperature feedback; the PID could grow warm or cold in response to player behavior. Unfortunately, peltier modules are extremely rigid, and would therefore conflict with Pluff’s stated goal of remaining soft and pliable if installed close enough to the surface of the toy for the temperature change to be felt. Audio feedback would be extremely desirable, but as with the peltier modules, speakers are rigid, and therefore not used in the PID. Ultimately, a Lilypad vibe
board was the only form of output device implemented in the PID, as it provided effective tactile feedback (Pluff’s purr) and was small enough to hide with a layer of padding.

Given the rate at which hardware shrinks in size and tactile footprint, it is not inconceivable that peltier modules, speakers, etc. could be revisited at some point in the future. Pluff is an ongoing project, and any advances in technology could impact the makeup of the PID in future iterations.

**Shaping User Behavior and Emotions**

Eliciting “Appropriate” Behavior

The underlying code for interpreting sensor input from the PID checks for two general categories of interaction, in addition to the specific actions which trigger Pluff’s tricks. These two generalities, positive and negative, were shaped for a practical reason, that of needing to protect the PID’s delicate hardware. While the PID is carefully insulated in layers of padding, and is far more deformable than a typical game controller or computer mouse, it is not completely immune to physical harm. If the PID were a more conventional interface device, made of plastic and metal, users would know to treat it as a breakable electronic item. However, the PID takes the form of a stuffed animal, and therefore implies that it shares other characteristics with these toys, namely being soft, deformable, and fairly tolerant of rough treatment. A child can stomp on a stuffed animal with no fear that the toy will be destroyed in the process. If a user were to stomp on the PID, they would quickly discover that the PID no longer functioned. There was a definite need to develop a method for instructing users to be careful with the PID, preferably in a way that would not destroy the narrative context of the Pluff character.
Thankfully, a narrative solution for this issue already existed. The game puts Pluff in the role of a pet, a role that comes with it a set of expectations for appropriate behavior. It is generally unacceptable to behave violently toward small furry animals, and that rule is appropriated for use in *Pluff*. Through Pluff’s emotional reactions to being mistreated (pouting, eventually crying, refusing to do tricks), the user learns that Pluff is an entity that is aware of its treatment in the physical world, and that rough treatment results in distress on the part of the sympathetic creature onscreen. It is entirely possible that this social pressure to "behave" will not be sufficient, and that users would mistreat the PID regardless. For the purposes of a proof of concept like *Pluff*, these users have been addressed but not entirely catered to. If *Pluff* were to become a more fully realized product, as opposed to a scholarly experiment, more care would need to be taken to ensure that the PID was as protected from physical harm as possible.

**Creating Emotional Engagement**

*Pluff* takes advantage of both the PID’s physical nature and the charisma of the onscreen NPC to engage the user emotionally. In particular, the combination of onscreen content and furry controller conspire to create the illusion that Pluff is alive. The Pluff character is aware of his surroundings via the PID, and reacts emotionally to his treatment via the screen and the PID’s "purr" behavior. Pluff has emotional needs and physical vulnerability; he reacts indignantly to being ignored (the PID receiving no input for several minutes), is pleased by affection, and is distressed by rough handling. Couching Pluff in terms of a live entity encourages the user to engage with the character socially, and on some level, emotionally.

In the onscreen character, facial features are simple and exaggerated, the body shape is distinctive, and fur is textured and subtly multicolored. These features carry over into the PID, helping the user create parallels between the cartoon they are seeing and the object they are holding. Users had no trouble seeing the connection between their behavior toward the PID and the reactions of the NPC.
To the user, Pluff as an entity is not the onscreen character or the PID, but an amalgamation of the two. This level of comprehension was most evident when observing users interacting with the game via the PID; they would make eye contact with the face of the PID when petting or otherwise directly addressing it, and then turn their attention to the screen to see Pluff’s in-game reaction. This change of focus suggests that both onscreen and physical components of Pluff were important to the users; they did not ignore the screen entirely, nor did they stare at the screen and become unconscious of the item they were holding, as would be expected with a typical game controller. Suspension of disbelief is achieved, helping the user to engage more fully with Pluff.

One reason for keeping the PID as close to a stuffed animal as possible, in terms of its feel and appearance, was to tap into existing user expectations about the nature of plush toys. Stuffed animals are traditionally receptacles for affection; they are designed to be hugged, petted, and even befriended. What’s more, stuffed animals are often associated, both through childhood play and media depictions, with storytelling rooted in imagination and suspension of disbelief. Winnie the Pooh, Calvin and Hobbes, and Toy Story, among many other works of fiction, present people with the assertion that stuffed animals have personalities and lives, but only within an imaginary realm. This helps the user to accept the onscreen version of Pluff in addition to the stuffed PID; it is only natural that Pluff’s engaging personality exists solely in the digital (imaginary) realm, because this dovetails nicely with what people already “know” about stuffed animals. Pluff uses all of these existing associations to advantage, establishing for the user from the outset how to think (and feel) about the PID. To quote Donald Norman, “We become attached to things if they have significant personal association, if they bring to mind pleasant, comforting moments” (Norman, 48).

Another reason for the PID’s stuffed animal roots is to avoid elements of the uncanny valley, as described by Masahiro Mori (Mori). Simply put, the closer a character gets to realism, the more its “unreal” characteristics will tend to stick out and unsettle. Robotic animal toys like Tiger Co.’s Furby,
Ugobe’s Pleo, and MIT’s Huggables™ suffer from the incongruity of their sophisticated behavior and engaging appearance contrasted with their extremely detectable electronic hardware. In the end, no matter how sophisticated the toy’s technology, the character is not believable so long as servo motors and other mechanical bits are tactilely detectable or worse, audible. The PID’s technology is not readily apparent, which allows the user to retain the suspension of disbelief and emotional connection that come from its status as a stuffed animal.

**Implementation of User Feedback**

**First Pluff Prototype**

The first version of the full Pluff experience included a prototype PID and a simplified version of the Flash game's exploratory mode. The PID possessed four flex sensors and an accelerometer, and used a USB connection to transfer data to a PC. The Flash component consisted of a static outdoor scene, with the Pluff character in the foreground. Users could produce a total of three "moods" in the onscreen character: happy, content, and distressed. Positive user actions toward the PID shifted the character's mood once in the positive direction. Dropping or shaking the doll resulted in an immediate shift to distress, while not interacting with the PID at all would shift mood once in the negative direction every 15 seconds (as if the character were upset about being ignored).

This setup went through several sessions of user interaction, with similar reactions in most cases. Generally, users responded emotionally to the character of Pluff, and did not have trouble connecting the physical character of the PID with the digital one onscreen. In particular, they had strong reactions to the character's distressed state. As soon as the distress behavior (a crying Pluff graphic combined with a loud clarinet trill sound) began, users would move quickly to pet or hug the PID, hoping to shift the onscreen character to a happier state.
Most users professed distaste for the PID's tethered connection to the PC, both because it reduced possibilities for movement and because it was easily unplugged, which tended to produce game-crashing errors. Several users requested a more varied experience. In some cases, this meant a broader emotional range for the onscreen character. In others, the desire was for a larger set of physical interactions with the PID.

Second Pluff Prototype

Taking cues from the first Pluff prototype, the repertoire of both the Flash game and PID were expanded. The onscreen character's emotional range has expanded to a total of 9 moods. Its behavior has expanded to include a set of "tricks", triggered by commands given through the PID. In addition to the exploratory mode, a guided "obedience school" mode was added to give some variety and structure to the experience. The PID itself was modified to run wirelessly through the addition of a battery and Bluetooth modem; a vibe motor added tactile feedback to supplement reactions onscreen.

In addition to tracking short-term changes in Pluff's mood, the Flash game tracks Pluff's moods over time. An aggregate score, largely an average of all game sessions with some weighting, is used to influence Pluff's overall "personality." If a user has been mistreating Pluff for several sessions in a row, but is careful and nurturing for one session, their version of Pluff will tend to stay in the more negative emotional range, despite the short term positive input. Likewise, if a user is generally kind and caring and on one occasion drops the PID, Pluff's overall mood would remain positive despite short term distress.
The second prototype is currently undergoing cycles of development and user testing. In particular, the expanded Flash game will require testing to ensure player comprehension. Results will be reported upon completion of this development phase.

**Successes and Failures of Pluff**

*Pluff* achieves its design goals, in that it expands the implementations of e-textiles beyond wearable interfaces, and it creates an emotional engagement not achieved by traditional game controllers. The PID’s multiple sensors and its integration with an external game system expand the range of possibilities for use of e-textiles in complex applications. Technologies produced during its development (the fabric breadboard and capacitive touch sensing) increase the sophistication of e-textile methods and capabilities, making them even more attractive as an electronics medium.

The stuffed animal form of the PID in combination with the charismatic onscreen character provide a level of connection between the physical behavior of the user and their emotional and cognitive engagement that is not common to traditional interface devices. In user tests, players generally responded with affection when presented with the PID. Pluff’s exuberant happiness produced amusement, and his upset state generated discomfort. When Pluff exhibited extreme distress, users would scramble to pet and hug the PID, in a manner reminiscent of an adult trying to comfort a screaming infant. On one notable occasion, a female user shook the PID in the course of interacting with it. On cue, the onscreen character began to cry. The user immediately held the PID close, hugging and rocking it in an attempt to improve Pluff’s mood. Most notably, she spoke both to the PID and the onscreen Pluff, apologizing for making the character cry. Such an empathic response is somewhat common for toys and, to a lesser extent, virtual characters, but it is not common for traditional interface devices.
However, while *Pluff* is a useful demonstration of the non-wearable possibilities of e-textiles, as well as an extremely engaging interface device, some aspects would benefit from further refinement. The Lilypad hardware, while indeed smaller and more readily sewable than conventional electronics, is still somewhat larger and more rigid than would be ideal. If the user knows where to look, the PID's electronics are detectable. It is possible to develop fabric-based PCB's that are far softer (Buechley, "Leah buchley - engineering"). With more time and expertise, it would be ideal to convert the Lilypad hardware to this more flexible structure, further reducing its tactile detectability within the PID. It might also be worthwhile to pursue a PID that is not furry; a wide variety of textures are available within the realm of fabrics, from silk to burlap, and all would provide interesting tactile experiences.

Perhaps the aspect of the *Pluff* project that would most benefit from further development is the onscreen Flash component. The game does accomplish its purpose in giving feedback to the user and helping the user learn how to use the PID, but the game could provide a much richer experience. As it stands, the game is largely a tech demo for the PID. Ideally, the narrative and world of the game will be much enlarged to provide the user more opportunity to connect with the Pluff character.

**Implications for Future Work**

There are two key features to be developed in future iterations of *Pluff*. One is the addition of offline data logging; users will be able to interact with the PID when it is not connected to the PC, and have those interactions impact gameplay when the PID is next connected. This should give a sense that the Pluff character is "real" even outside the game world, increasing the user's level of engagement. Another element that bears further investigation is the addition of a more involved narrative for the Flash game. Telling a story and expanding the world of the game should give more depth and
personality to the Pluff character, again increasing the user’s engagement with the experience.

In addition to *Pluff proper*, some techniques and design philosophies have developed which bear further investigation. In particular, the use of e-textiles outside the realm of wearables is an approach that should continue. If any textile can be embedded with electronics in a nearly invisible way, then everything from clothing to upholstery to bed linens can potentially be an electronic interface. The ability to add touch sensing, via capacitive sensors and embroidered pads, gives any textile the ability to be a tactile interface device. These advances need not be limited to clothing and personal accessories; temperature-controlled pillows, a chair arm with an embedded TV remote, and smoke detecting curtains all are immediate possibilities through use of this technology.

**Conclusion**

Though still in the proof of concept phase, *Pluff* succeeds in several key areas. The main character is engaging and encourages repeated and prolonged contact on the part of the user. The user’s connection with the Pluff character is unusually emotional when compared with typical player perceptions of video game controllers. The PID uses e-textiles to strong effect, achieving levels of hardware flexibility not possible with conventional materials. It also demonstrates that e-textiles can indeed be applied with good effect to interfaces beyond their more common wearable applications.

However, much work remains. *Pluff* is a beginning in the area of textile-based interfaces, but it is just one approach. The PID shows promise, both as the interface to the current Flash game and as an interface to other types of gaming experiences. And, as Pluff has demonstrated, e-textiles are an incredibly versatile medium with a great deal of potential for a wide range of tactile interface devices. It would be advantageous to pursue this area of inquiry further; *Pluff* is a start, but many, many possibilities remain to be explored.
References


