Inner Garden: an Augmented Sandbox Designed for Self-Reflection

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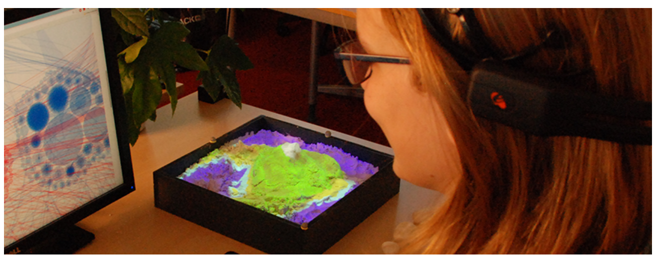

Figure 1: The sandbox resides on the side of the working space, allowing the user to monitor her inner state; she can also play with it to relax.

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Abstract
We present a prototype of an augmented sandbox where the sand is used to create a miniature living world, designed as an ambient display for contemplation and self-reflection. The landscape can be reshaped at any time. Once the sand is left still for a moment, the world starts evolving – vegetation grows, water flows and creatures move around – according to the user's internal state. We use a consumer-grade EEG and breathing sensors to reflect on frustration and meditative states of users, which they can monitor by looking at the sandbox.

Author Keywords
Spatial Augmented Reality; Calm Technologies; Tangible Interaction

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities

Introduction
Computational devices such as smartphones and tablets are now ubiquitous. We are close to the technology penetration rate envisioned by Weiser when describing ubiquitous computing [23]. However, one of the cornerstones of Weiser's vision was about creating *calm* [24]. When is the last time you felt calm when interacting with technology?

Do you ever feel calm checking emails? Indeed, as argued by Leshed [11], we seem to have used productivity tools to increase our overall pace of life instead of using the extra time to relax and make our lives easier. As knowledge work is getting more prevalent, this is becoming a problem, especially knowing the increasing body of research showing the negative impact of stress on health and productivity [12].

Mindfulness, contemplation and overall interoception – the ability to sense the origin of one's bodily signals – have been shown to have a positive impact on the ability to cope with stress and increase well-being [2]. Calm computing [24] and slow technology [4] have the potential to be a great medium to foster self-reflection [3, 17].

We propose a prototype of a contemplative toy (Figure 1), inspired by the god game genre, that combines Spatial Augmented Reality [21], tangible interaction [6] and physiological computing [1]. In god games, the player is in the position of influencing the environment itself, without incarnating any specific character; instead, the world is populated with semi-autonomous life forms. We make a clear distinction between a game and a toy. A toy has no inherent goals, constraints or rules. On the other hand, a game relies on these properties to create a more directed experience. Since our goal was to create a self-reflective and slow experience, mainly driven by self-motivation and curiosity, a toy seemed a better support. Using this approach, Paulos et al. [18] created toys to encourage children to explore their physical environment. Another example is the work of Karlesky et al. [8] who created seemingly meaningless tangible toys in order to explore the interaction that happens in the margins of creative work.

Our system is inspired by both the reflective and metaphoric nature of zen gardens as well as the playful and experimental nature of sandboxes. Zen gardens are all about careful

Figure 2: It is possible to interact with the sandbox at any time. Once the mini-world is reshaped, life will slowly start to evolve.

placement of elements and are often used for contemplative and meditative purposes. On the other hand, sandboxes call for interaction and experimentation. Our main goal was to create an ambient and meditative toy that could both include playful physical creation (Figure 2) and contemplation.

Related Work

Spatial Augmented Reality (SAR) [21] consists in displaying spatially coherent digital information in the environment, either using projectors or screens. SAR has already been used in conjunction with deformable materials. Illuminating Clay [19] has been the first system to combine the two elements. It uses clay to represent a landscape which can be directly shaped with the hands. The result of landscape analysis functions is displayed directly on the clay. Maas et al. [13] proposed Quimo, a clay-like material that embed AR markers (for tracking) which can be used to prototype physical objects through augmentation. SAR has also been used for sculpting foam [14] or clay [22]. Dynamic projection of landscape analysis and water simulation on sand has also been used in Disney theme parks [15]. Our system projects

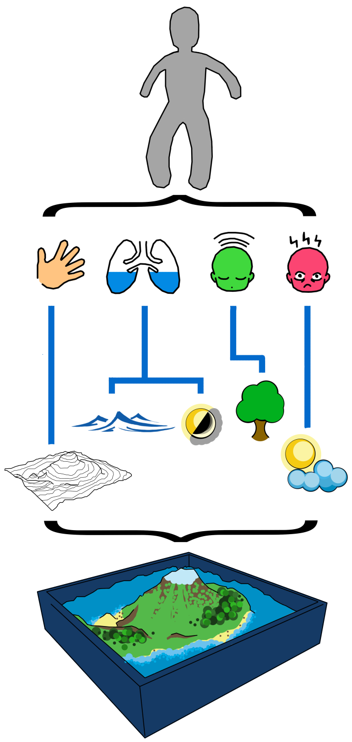

Figure 3: The user can influence the garden in several ways. Using his hands to change the topography, breathing to control the sea level, and meditating to foster life growth. The user's frustration and stress will be reflected on the weather and day duration.

information that does not only relate to the topology of the created landscape but is also an interactive canvas representing aspects of the user's inner state. Moreover, the projected simulated world is evolving on its own – e.g. elements in the world evolve without any user intervention –, similar to the artistic project "EfectoMariposa" [1].

The Quantified Self (QS) [26] is a movement that is increasingly popular. It consists in keeping a log of different metrics related to health or physical activity which can be used to gain insights about one's own body. Lately, extensions of the QS to cognitive tasks has also been proposed [10]. Different works relate to the tangible and social representation of this data. For example, Khot et al [9] have proposed a system that 3D prints a tangible representation of a recurring physical activity (e.g. running). Swarm [25] is a wearable system shaped as a scarf to mediate affect. Bodily signals have also been used in the context of calm technologies. Similar in spirit with our system is BreathTray [16], an ambient desktop widget that help users control their breathing patterns. Also, Hong et al. [5] proposed an ambient installation comprised of an articulated flower that mimics the posture of a user sitting nearby.

Your Inner Garden

The sandbox contains polymeric sand – a mix of natural sand and a polymer that results in "wet sand" that never dries out – which can be played with and reshaped at any time. The sand is augmented with dynamic graphics using an overhead projector. When the user stops reshaping the landscape, his or her world is "born" and starts living on its own. Grass grows, trees starts appearing and water flows. However, this process takes place slowly. The growth speed and overall health of the world are linked to the user's inner state (Figure 3). For instance, a user whose stress level is too high will see her world starts to dry out – trees withering without sunlight. Doing breathing exercises and lowering the stress helps to restore balance to the user's world.

[1] http://patriciogonzalezvivo.com/2011/efectomariposa/

The mini-world evolve in a deliberately slow manner, similar to the natural world itself. Three different components are simulated in parallel: time, weather and life. The passing of time is represented by day and night cycles. Weather is represented by the cloudiness of the sky. Since it is not possible to display floating elements using SAR, we instead reproject the clouds' shadows onto the world's surface. This particular aspect breathes life into the world, the subtle motion inviting contemplation. Finally, life in the world is represented as both vegetation and living agents.

Once the topological layout of the world is left alone for long enough, different life forms progressively appear in the world. The first thing to grow is vegetation. First, grass covers the surface of the land. Then, trees start to grow where grass already exists. If vegetation is luxurious for a sufficient amount of time, small living creatures will start wandering in the world. They are represented as small light sources moving around. They are only visible at night, reminiscent of what inhabited regions would look like seen from the sky. If the landscape is reshaped at a particular location, all life disappears in the affected areas – i.e. the simulation is locally reset. With time, life will prosper again.

The augmented sandbox acts like an ambient display [7], the state of the world reflecting some aspects of the user's inner state. We used two different physiological sensors for this early version of the prototype: a stretch sensor for measuring breathing and an EEG (ElectroEncephaloGraphy) device to measure frustrated and meditative states.

Breathing is a direct and controllable aspect of our physiology. For this reason, we created a direct mapping between

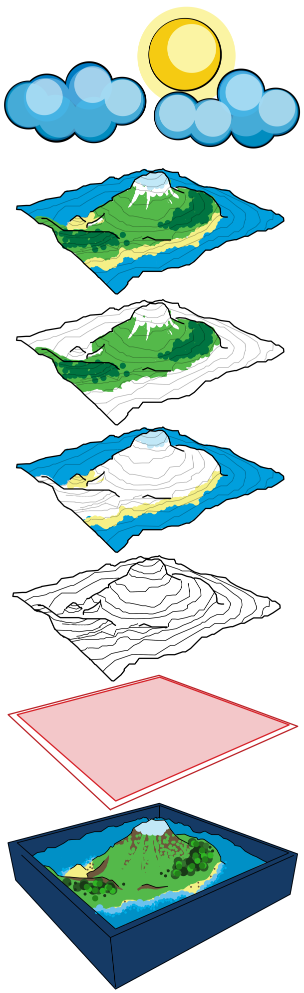

Figure 4: The layers of the simulation. From the bottom up: the resulting augmented sandbox, the tracking, the surface topography, the water and sand layer, the living organisms, and the combined layer affected by the sky.

the breathing and the sea level, creating subtle motion of waves washing ashore the world. Breathing *variability* controls the speed at which the day and night cycle operates. This increased variation of lighting conditions is a cue to bring the attention of the user back on the sandbox, as an indicator that he or she might be stressed and as an invitation to take a few deep breaths. Frustration is mapped to the weather conditions. A high frustration score will make the clouds travel faster, their density higher and, if a threshold is reached, storms will be created (lightning effects). On the other hand, a low frustration score would create slow moving clouds of low-density, reminiscent of a sunny day. Finally, a high meditation score has a positive impact on life conditions in the world. Taking a small time to meditate acts as fertilizer for the vegetation: grass and trees grow faster for a certain duration after a meditation session.

It is also interesting to note the social aspect of the system; a passerby, family member or colleague can glance over to see how well the user is doing. Moreover, multiple persons could have their inner garden on their desks, sharing their experience with each other.

Implementation

The system is composed by three subsystems (Figure 5): 1) the simulation, 2) the physiological controller, and 3) the spatial augmented reality setup. The application controlling the three subsystems is implemented using vvvv[2], a creative coding environment based on C# and DirectX.

The mini-world is composed by surface and sky simulations (Figure 4). The surface is a set of cellular automata, implemented as texture shaders. The base layer is a matrix containing the world coordinates corresponding to the inside of the sandbox, which we call the *topography*. Then, height and tangent maps are computed. With the terrain information, it is possible to determine, for example, which areas are underwater, and which are flat enough for life to thrive. The different layers interact with each other slowly over time, according to the user's state.

The sky simulation is comprised of the sun and clouds. The sun orbits around the mini-world, creating day and night. The clouds are not visible by themselves, but they cast shadows over the surface according to the sun's position.

The simulation parameters are controlled by a physiological module, connected to the Emotiv Epoc[3]. From the signals provided by the Emotiv SDK, we used the Affectiv suite, which enables the detection of different emotional states – frustration and meditation, among others. Using these metrics, the user influences the speed of growth and movement of the different elements in the world. A breathing sensor is also included – a stretch sensor attached to the user's chest connected to a Bitalino[4] board.

The augmentation is generated using a Microsoft Kinect v2 and an overhead projector. Every frame, the subsystem segments the section of the Kinect point cloud corresponding to the sand and passes it to the simulation system. Once the simulation is completed, the resulting textures are then reprojected onto the sandbox using the projector. Optionally, an Optitrack Trio is used to track the sandbox position and other small objects and tools. The setup is illustrated in Figure 6.

Discussion and Conclusion

In this work, we presented a prototype of an augmented toy designed to foster contemplation and introspection. We

[2] http://vvvv.org

[3] https://emotiv.com/epoc.php

[4] http://www.bitalino.com/

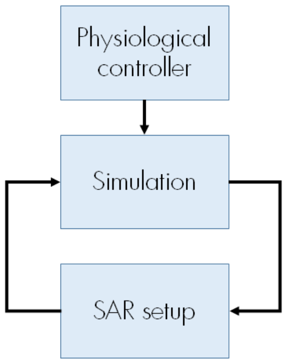

Figure 5: Subsystems of the inner garden, and their relationships.

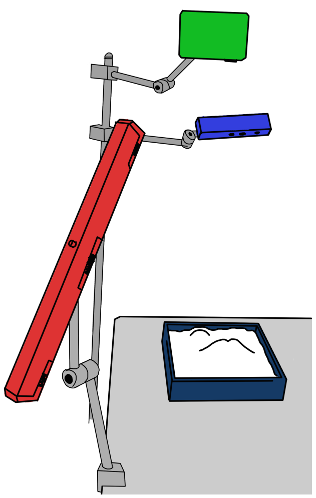

Figure 6: SAR setup, including a LG PB60G projector (green), a Microsoft Kinect v2 (blue), and optionally an Optitrack Trio (red).

proposed an implementation for a world in miniature that is influenced by the user's internal state. In the future, we want to study how such a toy could impact different users in a variety of contexts. The current metric-to-feedback relationship is naive, we want to study the actual impact of these mappings on the user in order to achieve the desired effect. We would also like to explore how to make the system more cohesive with the medium and the inclusion of less intrusive physiological sensors.

In order to study the effect of the inner garden, we plan to use the system over long periods of time – e.g. over a week. This way, we could explore both the effect of the ambient display on the user's stress levels, as well as the social impact. We are interested to see how users will feel when being put in charge of an artificial world. For example, are people more motivated to take care of their well-being when having a small world depending on them? Also, it will be interesting to see if this will create socially uncomfortable exposure, or, on the contrary, be a facilitator for empathy between coworkers or family members.

The integration of real elements within the garden will also be explored. For example, we envision having a nearby plant being part of the augmented world. Such elements could be interactive (e.g. [20]). The combination of virtual agents and real living elements could increase the presence, enhancing the feeling of connection with the natural world. Other objects such as rocks, which are commonly found in zen gardens, could also be placed over the sand. These rocks could represent tangible memories, or souvenirs, imprinted with snapshots of the user internal state at this moment in time. Placing the object in the sandbox could locally impact the miniature world based on the emotions it contains.

We could also provide the garden with its own personality, replacing or complementing the user's influence with random parameters – e.g. that would react differently to excitement or frustration. The garden would become more than an introspective display, turning into an agent to interact and dialog with.

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