Why Simulate? Hybrid Biological-Digital Games

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Abstract. Biologically inspired algorithms (neural networks, evolutionary computation, swarm intelligence, etcetera) are commonly applied in development of digital games. We argue that there are opportunities and possibilities for integrating real biological organisms inside computer games, with potential added value to the game's player, developer and integrated organism. In this approach, live organisms are an integral part of digital gaming technology or player experience.

To spark further thought and research into the concept of hybrid biological-digital games, we present an overview of its opportunities for creating computer games. Opportunities are categorized by their mainly affected stakeholder: game player, game designer, and bio-digital integrated organism. We clarify the categorization via numerous examples of existing hybrid bio-digital games. Based on our review work we present conclusions about the current state and future outlook for hybrid bio-digital games.

Keywords: Hybrid, bio-digital, computer games, animals, biological organisms, biotic games, bio-art.

1 Introduction

We have become used to applying biologically inspired algorithms in the development and design of computer games. Neural and evolutionary computation, swarm systems and other forms of self-organization, and various other biologically inspired techniques are now fairly commonplace in both science and computer games.

In a way, such techniques are simulations of biological processes, either abstracted, altered or enhanced to fit a particular purpose within the process of game design and development. We argue, however, that there are opportunities and possibilities for integrating *real* biological systems inside computer games, with potential added value to the game player, game developer and organism. With real biological systems we refer to plants, microorganisms, animals, and even complete ecosystems.

Using biological systems and components as part of (digital) technological solutions is applied in practice already. Particularly within the realms of robotics (e.g. [4], [13], [14], [15]) and artistic- and entertainment computing (e.g. [5], [9], [12]), but also more general engineering (e.g. [1], [19], [20], [23]) examples exist of biological systems that are intricately entwined within mainly technological systems. Perhaps the

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most famous example of such interactions is the Second World War project by famous behaviorist B.F. Skinner [26], in which he successfully trained real pigeons to guide missiles to strategic targets, for lack of an equally reliable technological solution for this task. Although this famous endeavor does not relate to computer games, it demonstrates how integration of a biological system solves a problem to which no technological solution is yet available.

More recently animal-computer interaction has appeared on the scientific agenda, a field analogous to that of human-computer interaction. It places the animal perspective at the heart technological development aimed at animals [17].

Naturally, very real disadvantages exist for integrating biological components into digital computer games. Practical issues arise in game maintenance, shipping, sales, and more. Dealing with microorganisms and cells may require a well-balanced biochemical environment. Games requiring exotic or trained animals are naturally commercially unattractive, and possibly illegal due to endangered animal protection laws.

Perhaps most importantly, animal welfare must be respected at all times. Ethical treatment of animals is a major concern within the bio-digital approach to systems design. Several commercial arcade crane-games exist[1] that challenge players to catch a live lobster from an aquarium with the aid of an electrically operated claw. Such games were criticized for causing harm to animals [22].

Legal restrictions have been implemented in many countries to fight maltreatment of animals for purposes of science, commerce, entertainment and otherwise. We strongly support and respect such restrictions. Moreover, we point out that within the emerging and dynamic realm of bio-digital systems particular concern is in place regarding the ethical treatment of animals and other organisms.

Despite obvious disadvantages, let us view the opportunities of this approach. To spark further investigation and creativity around the topic of hybrid bio-digital computer games, we discuss these opportunities for the three major stakeholders of this approach to computer game design:

1. the player,
2. the developer,
3. the organism integrated into the computer game system.

As the developer, we mean anyone with an interest in designing and developing games for any purpose (e.g. commercial gain or scientific data gathering). Interests of player and developer may overlap, since what is good for the player should be at least appealing to developers. Similarly, interests of organisms and players may overlap.

We clarify the proposed opportunities with examples of existing integrations of real biological systems within computer games. For the sake of brevity we do not discuss examples from the realm of artistic computing, unless they take the form of a computer game. Bio-art, the artistic discipline that works with real biological systems,

[1] E.g. “The Lobster Zone” (Lobster Zone Inc., USA), “Love Maine Lobster Claw” (Marine Ecological Habitats Inc., USA), and “Sub Marine Catcher” (unknown manufacturer, Japan).

is currently receiving much attention[2]. Overlap exists between bio-art and hybrid bio-digital computer games, and concerns regarding ethics of working with organisms are shared between disciplines.

Also, games exist that integrate real plants into their digital systems (e.g. [29], [32]). Although these are highly interesting and involve biological components, they are not discussed here. We choose to focus on more active biological entities, such as animals, microorganisms, and neurons.

Moreover, our attention is directed towards the integration of organisms within *digital* games only. Outside this scope falls for example "BioPong" [25], a Pong-style arcade cabinet game in which the pixelated ball is in fact a cardboard square attached to a real cockroach. Players must prevent the cockroach from passing their physical Pong-paddle. Although BioPong emulates a classic computer game, it is in fact not a digital game itself.

For a more widely scoped overview of organisms integrated in digital artistic and entertainment systems we refer to another publication by the authors [10]. This study focuses on opportunities for hybrid bio-digital computer games.

2 Opportunities for Players

2.1 Interspecies Awareness

For the benefit of the player, an important distinction that can be made is whether or not one is aware of the biological organism's role within the game. In particular with real-time integration of animal behavior in the game, the realization that one plays against (or with) an animal may change the player's view. In a sense this distinction is comparable to that between playing against a simulated or a live opponent, in that it may affect aspects of competition, willingness to collaborate, and even endurance.

Stephen Wilson's "Protozoa Games" [30] is a series of digital games that let humans compete against a variety of protozoa, single-celled parasitic organisms. Human players are tracked with a camera; the protozoa are recorded inside a petri dish via a microscope. In several games humans and protozoa can compete in agility. With lights and audio picked up via microphones, players can attempt to influence the protozoa as part of the gameplay. Similarly, in Wilson's "IntroSpection" installation [31], players can play games with projections of cells taken directly from their own mouths and placed under a microscope.

2.2 Enabling Care

The care-relationship that exists between a pet and its owner was extensively exploited in computer games. Tamagotchi (Bandai Co. Ltd., Japan, 1996), Nintendogs (Nintendo Co. Ltd., Japan, 2005), and many similar games offer the enjoyment of

[2] For a list and discussions of various bio-artworks, we recommend the following webpage: `http://www.we-make-money-not-art.com/archives/bioart/`

caring for a virtual pet. Similarly, digital games can mediate between caregiver and real pet. In situations where physically interacting with a real pet is not possible, digital interaction may be a useful alternative. Moreover, such interaction makes multiple caregivers and a more transient pet-caregiver relationship possible.

In analogy of the once popular Tamagotchi digital pet game, the "Tardigotchi" artwork [16] houses a living tardigrade organism inside a brass sphere. While the organism can be seen through a viewing hole, its digital caricature is visualized on an LED screen. Buttons feed both the digital and real creature, and players can activate a heating lamp for the tardigrade by sending the digital creature an e-mail message.

The "Cat Cat Revolution" [21] interspecies computer game (cat-human) attempts to include pets into their owner's digital gaming experience. The cat owner controls a virtual mouse via his/her smartphone. The virtual mouse appears on a tablet-computer, where it can be chased by the cat. The game detects when the cat's paw hits the virtual mouse. Users expressed positive feelings towards the game's role in pet-owner daily activities and the pet's well-being and freedom to play.

2.3 Education

Traditionally, games (both digital and non-digital) have been widely applied as educational tools. By extension, dealing with real biological systems via digital games can educate about biology, offering realizations and interactions that would not be available through simulation.

The only projects that mention educating the player as a *specific* purpose are Stephen Wilson's aforementioned "Protozoa Games" [30] and "IntroSpection" [31] installations. However, it holds true for many other existing projects that through awareness and curiosity about the biological component, informal learning may be expected to occur.

2.4 Behavioral Variability

Even when a player is unaware of the interaction with biological organisms, its effects may nonetheless be relevant. For example, the behavior of virtual characters may be steered by real-time behavior of organisms. In this way behavioral models can be surpassed, potentially leading to more natural and unpredictable behavior.

In our earlier study entitled "Animal Controlled Computer Games: Playing Pac-Man against Real Crickets" [11] we researched the possible use of live animals for real-time behavior generation in computer games. In a Pac-Man style video game, the behavior of virtual opponent characters (ghosts) was derived from that of live crickets inside a real maze (Figure 1). The location of the player-controlled Pac-Man character within the virtual game was translated to the real maze via vibrations. Use of real crickets led to unexpected and interesting behavior of the virtual game characters.

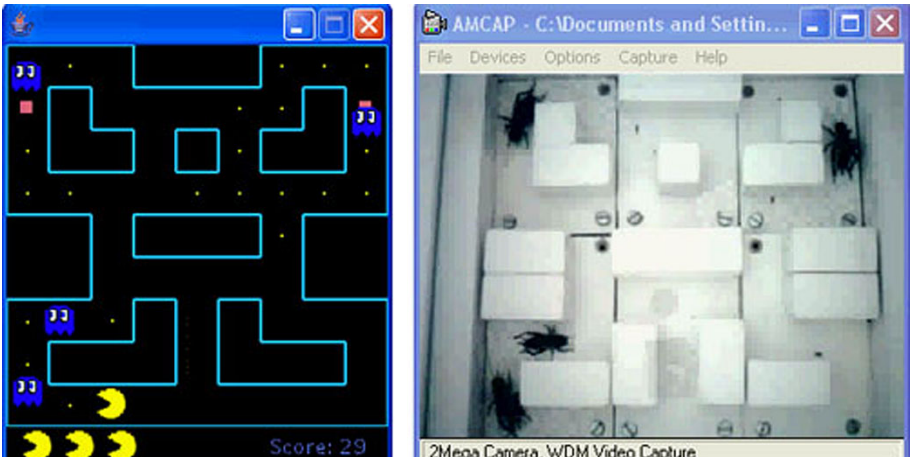

Fig. 1. Screenshot of Pac-Man style game (*left*) with four "ghost" opponent characters, and camera capture of the physical facsimile maze (*right*) containing four live crickets (Images from [11]). The crickets control the ghosts in real-time. The position of the player-controlled "Pac-Man" character is translated into vibrations within the physical maze.

3 Opportunities for Developers

3.1 Perception and Processing

As demonstrated in B.F. Skinner's "Project Pigeon" [26], complex control issues can be solved by using natural sensing and processing capabilities of organisms. The same concept was demonstrated in a digital environment by Garnet Hertz's "Cockroach Controlled Mobile Robot" artistic project [13]. Similarly, designing complex (behavioral) control models in games could be avoided by stimulation and sensing of real organisms in a suitable environment.

Using a grid of 60 electrodes, DeMarse and Dockendorf [8] stimulated and recorded the activity from a network of 25.000 rat neurons. This network was connected to a consumer flight simulator, and successfully trained to act as an autopilot. By stimulating the neurons with information about deviation from level flight, they slowly learned to control the flight simulator's pitch and roll, until they were able to maintain straight and level flight.

3.2 Crowdsourcing and Gamification

Given the ongoing scientific interest in biological systems, it is not surprising that interest has been expressed to apply hybrid bio-digital games for scientific data gathering. Moreover gaming can offer a platform and community for crowdsourcing projects. Applying games for crowdsourcing is closely linked to the strongly

emerging paradigm of *gamification*, the use of gaming elements to engage potential audiences in various tasks [18], such as problem solving, data collection, and learning.

Riedel-Kruse *et al.* [24] incorporated biological processes of real microorganisms (not simulations) into several variations of classic game titles as Pac-Man, Pong and pinball. To achieve their game-tasks, players control in real-time microscopically observed paramecium organisms by way of electrical fields or chemicals released from a micro-needle. As such, biological processes are an integral part of the gameplay – a concept they term "biotic games".

Based on their successful implementations, the authors propose to realize complex bio-engineering tasks by applying crowdsourcing mechanics to biotic games [24, p.19]. Essentially, by playing the biotic games players would perform experiments on actual living biological matter, and thus contribute to solving scientific problems. Unfortunately, no concrete bio-digital crowdsourcing was yet realized.

3.3 Organic Design

Perhaps slightly more experimental are efforts to employ organisms for level-design of games. Through the process of self-organization, groups of microorganisms and cells (and even larger organisms) can collaboratively create structured spatial patterns [7]. Think of honeycomb patterns in a beehive, and zebra skin stripes generated by collaborating pigment cells. Such evolving structures and patterns could be used to create or dynamically grow intricate landscapes, structures and levels for digital games.

In a recently started project, Wim van Eck aims to derive virtual worlds in real-time from microscopically observed living materials, such as growing cellular cultures or fungi. Visitors of these virtual worlds are confronted with their constantly changing and transient nature, reflecting the process of organic growth. By concurrently changing the conditions to which the organism is subjected, its growth dynamics can be affected, and consequently the virtual landscape. The virtual worlds and interactions designed in this project will be applied to gaming applications, yielding organic and transient level design.[3]

4 Opportunities for Animals

4.1 Welfare and New Forms of Care

As mentioned earlier, the animal-caregiver relation can be focus of bio-integrated computer games. Although animal welfare should come naturally for those providing care, computer games can aid in several ways. Firstly, mutual games that are typically shared between pet and owner can be played over greater distance via tele-operating methods. This makes it possible to maintain levels of care in physical absence. Secondly, via hosted games multiple players can act as caregiver for a single animal.

[3] For information about this project, contact author Wim van Eck.

Remote pet-owner interaction is exactly what the "Metazoa Ludens" project [27] [28] pursues. The position of a hamster or other small pet inside a closed environment is tracked, and represented as an avatar inside the player's computer game. Simultaneously, the pet is tempted to chase moving bait inside its enclosure – the bait's movement representing the movement of the player's avatar inside the game. Even the terrain inside the pet's enclosure is manipulated by actuators to mimic the virtual terrain of the computer game.

According to the creators, their setup enables human-pet interaction "on an equal level in the virtual world (which is impossible in the physical world)" [28, p.308]. From studies using hamsters, it was furthermore reported that regular play in Metazoa Ludens increased overall body fitness in the hamsters and that over the study period they increasingly chose to play, which indicates a positive desire to play the game.

4.2 Fighting Stereotypy

A special case for animal welfare deserves attention here, since interspecies computer games are a very real solution to the problem of animal *stereotypy*: repetitive behaviors in captive animals caused by inadequate mental stimulation [6]. Computer games that let human players interact with captive animals have been proposed, and are currently researched, as a method to enhance mental stimulation for the animal. Naturally, actions directed towards the animal must be bound along multiple parameters, such as type of interaction, intensity and time.

In the Netherlands captive pigs have the legal right to be provided with a toy. However, in practice the toys provided are insufficient for adequate mental stimulation. In April 2011, the Dutch Cultural Media Fund awarded a grant to the "Playing with Pigs" project [2]. This research project plans to develop a tablet-computer based game entitled "Pig Chase" [3] that lets users play with captive pigs in an effort to provide pigs with more fitting mental stimulation (Figure 2). Further goals are to design new forms of human-pig interaction, to study opportunities for new human-pig relations, and to let both species experience the cognitive capabilities of each other.

5 Discussion and Future Outlook

We have presented an overview of opportunities of the hybrid bio-digital approach to creating computer games. In this approach, live organisms are an integral part of digital gaming technology or player experience. The overview categorizes opportunities by their mainly affected stakeholder: game player, game designer, and bio-integrated animal. Overlap in these categories exists, and perhaps further opportunities were overlooked. Also, project examples that were mentioned to illustrate a particular opportunity, may have well applied to other opportunities also. Nonetheless we view this endeavor as a successful attempt to organize what hybrid bio-digital work is relevant to the domain of computer games.

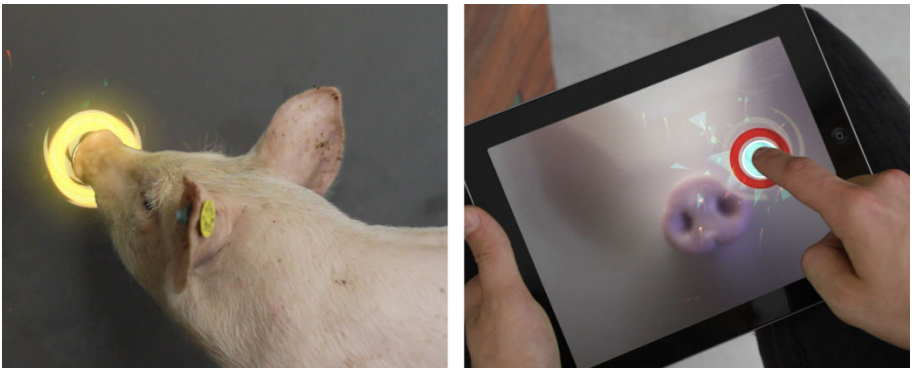

Fig. 2. Interaction modes within the inter-species game "Pig Chase": pig interacting with virtual object on a large touch sensitive display (*left*), and human interacting with tablet-computer (*right*) to control the virtual object and view the pig interaction (Images from [3]). The game objective for the human is to guide the pig's snout to an on-screen target, whereas successful actions by the pig trigger colorful visual projections on the large display.

Overseeing the reviewed projects, several observations arise. Firstly, without exception, all projects can be classified as experimental, exploratory and often artful endeavors. No truly commercial applications in computer game design were realized, nor were indications given for any commercial use.

Secondly, the applications of biological components in digital games have thus far been very diverse with respect to their aims. From controlling part of a flight simulator to growing virtual gaming environments, organic components have been applied for a plethora of purposes. No single "killer app", or highly desirable use of biological systems in digital gaming, stands out from the overview.

Thirdly, no paradigms have been put forward that offer handlebars to hybrid bio-digital games design. The number of working methods and working hypotheses in the reviewed projects seems to rival the number of projects itself. None of the proposed working methods was developed to the extent that it can be named a possible paradigm.

Fourthly, it is yet to be discovered which of the proposed bio-digital solutions (be it neurons to solve a multivariate control task, or growing cell cultures to design game worlds) will outperform their fully technological counterparts. In other words, when do we need organisms, and when does technology suffice? With regards to this question, we present the reviewed projects with an open mind, but acknowledge that modern technology is not only more practical, but often sufficiently potent.

Fifthly, given the above observation, it appears that most interesting opportunities benefit players and animals, and to a lesser extent game engineering. Therefore, we expect future advances in hybrid bio-digital game development to be stronger on the game-conceptual front, than in terms of engineering success.

All this is not to say that the bio-digital approach to computer gaming has a limited future outlook. Perhaps some proposed ideas will not advance to become wider applied, while others may open doors to gaming concepts that are yet to be envisioned.

Perhaps behavioral variability of in-game characters cannot be simulated to the extent desired by players, necessitating use of real organisms. Perhaps inter-species gaming will develop to become popular in its own right. One approach that in our view stands out in terms of future applicability and potential benefit to both animal welfare and innovative gameplay, is exemplified in the project "Playing with Pigs" [3].

Finally, we trust that our contribution, in the form of this combined position paper and short review, sparks further thought and research into the concept of hybrid biological-digital games.

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