CREATING BELIEVABLE CHARACTERS USING A SYNTHETIC PSYCHOLOGY APPROACH

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ABSTRACT

The aim of this project is to make simulated characters in interactive real-time software scenarios more believable by increasing the personality of their behaviour. This will be achieved by implementing biologically inspired Artificial Life (Alife) architectures into their control mechanisms.

The method to achieve this is inspired by the constructionist “Synthetic Psychology” approach adopted by neurologist Valentino Braitenberg (Braitenberg 1984). The architecture described in this thought experiment is comprised of a network of functional components and is an abstraction of the neural-architecture of human and mammal brains. The objective of this project is to implement a memory-prediction mechanism (Hawkins and Blakeslee 2004) that will enable virtual characters to behave in unpredictable, unique and interesting ways and allow them to become more sensitive to their environment and events, thus further suspending disbelief.

In addition to proposing a process for creating simulated characters we also aim to evaluate a method of automatically detecting emergent behaviours exhibited by characters using Kohonen self-organizing maps (SOM). SOMs have proven useful in finding emergent properties in systems from other fields such as usability analysis, marketing and medicine. We believe this capability can assist during the process, which would otherwise require long-term observation for evaluation.

Implemented using *Microsoft Robotics Developer Studio 2008*, this project will produce a series of prototype virtual “Vehicles” based on the designs found in Braitenberg's work, but in some cases amended with more recent findings about the neural architecture of the brain as described by Hawkins (Hawkins and Blakeslee 2004), Bonhoeffer (Engert and Bonhoeffer 1999) and Braitenberg himself.

INTRODUCTION

Creating believable characters is an important challenge in current media, such as films, video games (Champandard 2008) and other interactive entertainment applications for which they have also proven to be useful and engaging (Maes 1995). While the visual fidelity of recent products is approaching photo-realism, new problems have emerged. Interactive simulations and movies alike now often feature crowds of virtual characters, either as stand-ins for human or animal actors, or to populate the gigantic open worlds of modern videogames. This has created a new problem for character animators: the need for diversity in the behaviour of the characters. If this need is not fulfilled, even the most photo-real imagery will not convey a sense of reality and suspend disbelief.

With increasing processing power, computer graphics (CG) tool developers were able to develop sophisticated simulations of the physical properties of materials and objects. More recently, software such as “Massive” (Regelous 2007) and “Natural Motion” (Naturalmotion 2005) were among the first of a new kind of software that uses artificial intelligence to control the animation and behaviour of simulated characters. These tools are aimed at reducing the workload on animators by automating previously hand-made tasks such as animating large crowds of characters or making characters react to physical influences. Our project aims at creating interactive characters that are unique in that they act upon their own predictions concerning their current situation.

To fulfil this aim, this research proposes the prototypical development of architectures based on Braitenberg's more advanced designs, which deal with biologically inspired control systems for cognition, trains of thought, prediction/planning and eventually personal preferences and desires. This research should provide insight into the requirements for creating believable agents in virtual environments and provide a tangible evaluation of the theories of one of the most eminent brain researchers of our time.

RELATED RESEARCH

The use of Braitenberg's Vehicle designs (Braitenberg 1984) as a basis for research is grounded in a strong personal agreement with his constructivist (in this case also connectionist/ biologically-based) methodology and the question whether it is possible to implement his thought experiment using current consumer technology. Previous work in this area (Lambrinos and Scheier 1995) (Hogg, Martin et al. 1991) (Koball and Wharton 1988) (Tu and Terzopoulos 1994) has often referenced Braitenberg's simpler architectures (Vehicles 1-5) as its inspiration, but the more complex architectures (Vehicles 6-14) described by Braitenberg have never been fully realized.

In his work, Braitenberg describes a process for creating autonomous robots, or *Vehicles*. He refers to the process as "Synthetic Psychology", which Braitenberg states is an insight that he calls the "law of uphill analysis and downhill invention (Braitenberg 1984)[pg.20]. His claim is that it is much easier to invent machines that exhibit complex behaviour than it is to guess the internal structure of such a machine from observing its behaviour. Thus his book describes an iterative methodology that adds components with the intention of creating more complex and "interesting" behaviour, which differentiates his work from more top-down, goal oriented endeavours.

The nature of the book is that of a thought experiment, meaning that while most of what it describes is grounded in reality, the author does take the liberty of introducing fictional components if they are required (to replicate a given mechanism found in biological brains). For example he introduces a set of special wires that posses properties similar to the connecting matter (axons, dendrites) found between neurons in biological brains (Braitenberg 1984)[pg.29]. Functionally, these fictional components can be simulated (as he states himself in a footnote), which gives rise to our proposition that his architectures can be implemented

The description of the *Vehicles* only forms the first half of his work. The second half contains biological notes on his *Vehicle* designs. These notes contain detailed descriptions of the biological systems and references to the work that inspired the designs. These notes, alongside later work by other researchers provide helpful pointers for alterations to his original designs.

Below is a list of examples of other research projects and commercial products that are not directly related, but provided inspiration to the direction of this project:

Artificial Fish

The artificial life CG fish created by Demetri Terzopoulos, Xiaoyuan Tu and Radek Grzeszczuk in 1994 (Terzopoulos, Tu et al. 1994) are closest to the work proposed here. Designed as "self-animating graphical characters" they aim to realistically simulate the behavior of various piscine species interacting with one another in a virtual oceanic environment. Terzolopous fish fulfill the criteria of a biologically inspired biomimemic architecture in the sense that they use a muscle-actuated physically simulated body paired with simulated retinal imaging vision to locomote and detect situations (Terzopoulos 1999).

Natural Motion

Natural Motion (as a company) has created a collection of software tools utilizing a biomimemic approach to body simulation similar to the muscle-actuated body found in the artificial fish referenced above. They refer to this technique as Dynamic Motion Synthesis (Naturalmotion 2005). Using "biology-inspired controller approaches" they provide a series of behaviours such as jumping, walking or grabbing hold of objects that simulated characters can perform dynamically, meaning that interaction or interference with the character is still possible while it is performing a given behaviour.

Massive

An example of a tool that addresses the problem of animation diversity in crowds successfully in the film domain is the software "Massive" by Stephen Regelous (Regelous 2007). "Massive" was used to create the Oscar winning CGI effects of battling armies in the "Lord of the Rings" trilogy and was innovative in that it gave each individual character its own perception and behaviour controller. Each soldier would thus "fight for himself"' and depending on the "perceived" situation could flee, attack or defend. The result was a dynamic battlefield, with individuals and groups of soldiers fighting, shifting positions and defending each other, creating chaotic and believable mayhem.

Duncan Sheepdog

Isla's Duncan sheepdog (Isla and Blumberg 2002) includes a predictor coupled with a retinal image system to learn and predict temporal events. This initially sounds precisely like the mechanism employed by Braitenberg, but the implementation chosen by Isla is very different. He uses a discrete representation of probabilities of the location of objects in the world called a "probabilistic occupancy map (POM)". All temporal reasoning and prediction is performed using this two-dimensional discrete representation.

Oz Project

The Oz Project run by Joseph Bates in 1992 (Bates 1997) attempted to simulate believable characters based on principles from classical animation (Thomas and Johnston). The so-called Woggles that inhabit the simulation use a goal-directed behaviour-based architecture based on those developed at M.I.T by Pattie Maes (Maes 1995) and Rodney Brooks (Brooks 1985) in the late eighties.

For deciding which emotion to portray given a certain event, they used the work of Ortony, Collins and Clore (Ortony, Clore et al. 1988). This system provides a rigid correlation between the current event and a specified emotional reaction, but does not incorporate a world model or planning (foresight) of any kind. The emotional reactions are predefined by the designer of the character. This lead to discussions within the project group about the suitability of the chosen "event/emotion" correlations. For example, during a user test, a seemingly illogical behaviour caused by an error in the code was perceived as the most interesting. It caused more detailed interpretations of the creatures' emotional state than all the deliberate correlations elicited (Bates 1997). In his evaluation of the Oz project Bates observes that they did not incorporate systems for revealing the thought process of the Woggles (which would require a system for planning or foresight).

METHODOLOGY

Initial work was based on Macromedia (now Adobe) Flash. Running in a simple 2D environment, this work served to implement the *Vehicle* architectures found in the early chapters of Braitenberg's work. A custom physics engine was used to simulate the collision behaviour of objects and the movement of a two-wheel differential drive.

Using a community of *Vehicles* in an adversarial game context, we were able to demonstrate "interesting" and apparently emergent behaviours. Movement and enemy evasion controllers are inspired by the Braitenberg Vehicle 2 architectures "fear" and "aggression", as seen in Figure 1. Note that the behaviour of crossed and un-crossed connections is exactly the opposite of that described in Braitenberg's book, due to the fact that we use distance measurements instead of "heat" or "light".

Figure 1. "Fear and Aggression" Vehicle 2 architectures:

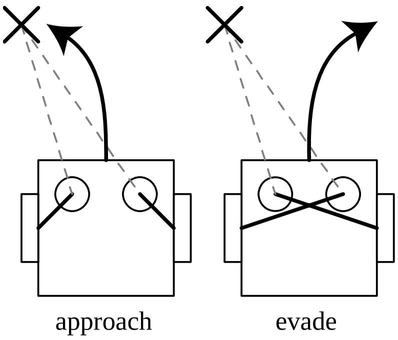
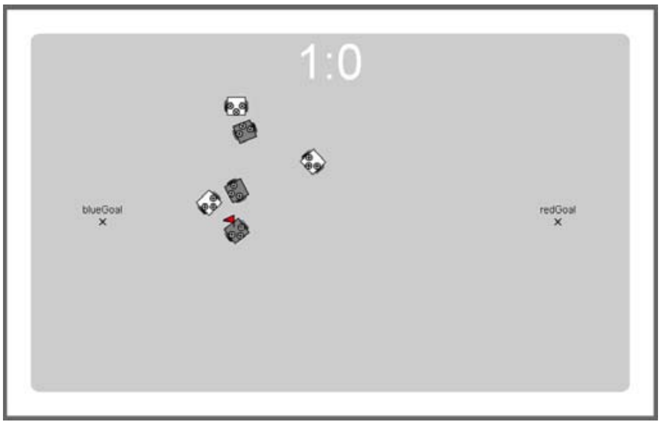


Figure 2 is a screenshot of a game in progress in which the aim is for each team to "capture the flag" by collecting it from the centre of the court and returning it to their base- all the while stopping the other team from doing the same.

Figure 2. Screenshot of Flash-based Braitenberg prototype:



Based on this initial success, we are currently developing an agent inspired by Braitenberg's Vehicle 8. This architecture has a fly-like compound eye constructed from an array of photosensitive cells. The aim is to implement neural layers that provide the agent with object and movement detection capabilities (similar to the behaviour of the visual cortex of mammalian brains).

To simulate a virtual eye we needed to move from a simple 2D simulation environment to a high-fidelity rendering engine.

The current prototype is being developed in C# using the *Microsoft Robotics Developer Studio 2008* (MRDS) framework, which uses the *Microsoft XNA* Graphics renderer and *AGEIA* physics engine. *XNA* is suitable for testing the applicability of our architecture in a gaming context as it is used in current commercial gaming products such as the *XBOX 360 Live Arcade* game Schizoid. *XNA* is compatible with the XBOX 360 hardware and windows computers and is part of an effort by Microsoft to support independent game developers. *AGEIA's PhysX* physics engine is one of the leading middleware solutions for game physics. *AGEIA* was recently acquired by graphics card manufacturer *NVIDIA*, providing GPU based hardware physics acceleration for systems using *NVIDIA* graphics adaptors.

Another reason why we chose MRDS is its sophisticated Concurrency Coordination Runtime (CCR) environment, which prepares our implementation for being ported to hardware that supports massively parallel operation if this is required at a later stage of the process. Furthermore, the Visual Programming Language (VPL) provided with the framework is a useful tool for prototyping different agents, while also providing a diagrammatic visualization of their architecture.

The virtual compound eye will consist of an array of virtual cameras that are configured to have a very low resolution and a short focal length in order to mimic the behaviour of photocells (measuring brightness values instead of capturing full-colour images).

Once the compound eye is constructed we plan to implement memory into the architecture, simulating what Braitenberg calls "threshold devices" and "Mnemotrix" and "Ergotrix" wires, which essentially resemble an artificial neural network. Threshold devices represent point neurons, which become active when they receive an input of a given strength from another device or sensor. Mnemotrix wires can be modelled as the connection weights between these associated threshold devices. Ergotrix wires are like Mnemotrix wires, but their increase in weight is governed by the synchronicity of activation timing of the associated elements.

Using these parts we construct sensory layers for different aspects of perception such as object detection, movement detection and symmetry. Two examples are given below. Further layers that will be implemented are described in detail in chapters 8 and 9 in Braitenberg's work (Braitenberg 1984).

Figure 3. Object detection layer. If groups of photocells are active at the same time a threshold device "neuron" will become active signifying an "object" in the visual field.

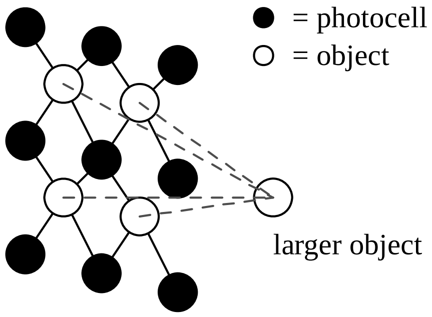
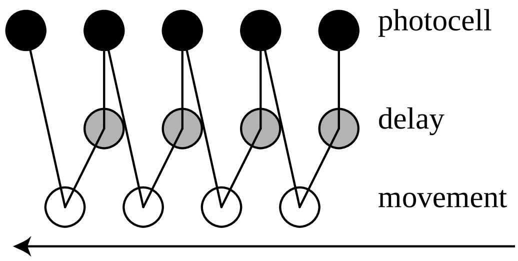
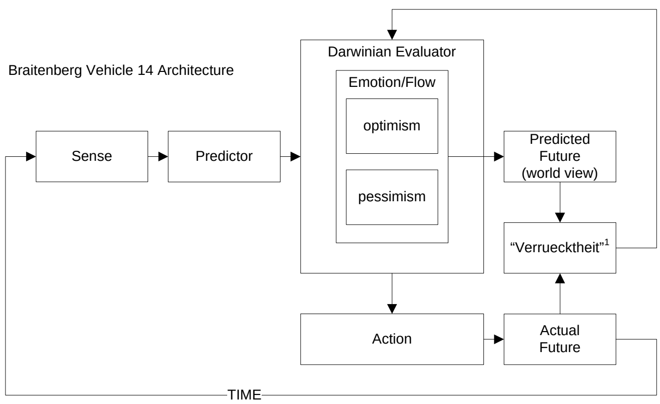


Figure 4. Movement detection layer. Movement "neurons" will become active when input is received from both a photocell and its neighbour via the delay element.



Finally the auto-associative feedback-loop design of memory in the brain will be modelled in the form of a "predictor" mechanism that allows the agent to act on the basis of its own predictions of the future, instead of reflexively acting on its current observation. This is achieved by utilizing the layers of "Ergotrix wires" that store information about temporal sequences perceived by the agent. This mechanism is described by Braitenberg in chapters 13 and 14.

Figure 5. Flow diagram of memory-prediction architecture:



We propose a novel technique to analyze behaviour data. Detecting emergent behaviour is a notoriously difficult task. However we believe that by using a neural-network Kohonen SOM we will be able to visualize the dominant emergent behaviours that the agent performs over time. Although these are best observed manually, it becomes infeasible to observe the simulations in real-time if multiple agents are present, or long term tests are run. It is therefore necessary to obtain a statistical summary of how the agent was behaving and what it was "thinking" during the test.

This statistical analysis method is well established in other fields such as medicine, business and usability analysis, but to our knowledge has not been used to analyze the emergent behaviour of interactive agents. Therefore we believe it has potential, but it has to be evaluated and verified separately for its validity as an observational tool. This verification will happen by running both expert analysis (an observer recording what she thinks are emergent behaviours) and Kohonen data analysis in parallel and comparing the subjective impression of the observer with the supposed emergent behaviours visualized by the SOM.

DISCUSSION AND RESULTS

We believe that the introduction of biologically inspired control approaches will add to virtual characters an aspect of "personality" which was previously only possible when "scripted" by an animator or author. These characters will act based on their own experience and will represent a very simple form of simulated life (Alife). The aim of this project is to realize this goal under the condition that the agents produced can be employed on consumer-grade hardware, differentiating this project from other research endeavours that aim to produce the most realistic replica of biological control structures as possible. Our aim is not to create a realistic replica of a functioning brain. We aim to produce interesting, emergent behaviour by employing techniques that retain the noisy and chaotic nature of data as it passes from sensory systems to actuators. Previous applications of AI in games and films have tackled the "cleanness" of behaviour by artificially adding random factors or fuzzyness to data, but we believe that this destroys the illusion of an intricate connection between the agent and its environment. Braitenberg's thought experiment seems to describe a robust methodology for tackling this task and we expect to see intriguing prototypes in the coming months.

Results describing the success of the Synthetic Psychology process in creating believable agents are expected by the end of 2009. It is our hope that by then we will have successfully developed an agent that uses simple retinal vision to navigate a virtual environment and implements the predictor mechanism described by Braitenberg to act on internal plans instead of direct sensual input.

We expect the Kohonen SOM analysis method to be useful in analysis the emergent behaviour of virtual agents. The evaluation of Kohonen SOMs as a suitable analysis tool is planned to be completed by the end of this year (2008), after initial prototypes are available for evaluation purposes.

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