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An Introduction to Genetic Profiling

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Abstract. This paper highlights the latest stage of an ongoing research project, primarily focussing on generating artificial anthropomorphic behaviour-sets for computer-generated non-player characters (NPCs). Building upon work presented in previous papers, this research highlights the latest results obtained from an investigation evaluating the anthropomorphism, (i.e. human-likeness) of several computer-controlled synthetic humans, controlled using artificial behaviour-sets generated by a new Artificial Intelligence mechanism, 'Genetic Profiling'. In addition to providing an introduction to the new mechanism, this research also serves to highlight how Genetic Profiling can potentially be applied to investigative scenarios in Computer Science projects outside the recreational games related context largely used by this project.

Keywords. NPC Behaviour, iWorlds, Mimicry, Evolutionary Algorithms, Intelligent Environments.

Introduction

It can be argued that one of the ultimate destinations of Computer Science will be to someday produce a system capable of replicating a human level of intelligence. For now that feat still resides firmly within the realm of science-fiction and this project has no intention of trying to change the status quo. The ultimate goal of this project was to attempt to create an alternative mechanism that could potentially act as an interim until the development of the ultimate human-level Artificial Intelligence system. The desire was to let computer-controlled Non-Player Characters (NPCs) exhibit decision-making and action patterns resembling performances demonstrated by real people in similar situations. Although other Artificial Intelligence mechanisms already exist for such purposes, the performances they produce often lack realistic anthropomorphic behavioural patterns. This is especially an issue for computer games, where poor controller Artificial Intelligence can result in NPCs performing stupid actions, which in turn can potentially ruin the enjoyment and immersive properties perceived by the players. Consequently, a new Artificial Intelligence mechanism, (UK Patent Application No. 1012243.0), combining elements of Mimicry and a modified form of Genetic Programming, was introduced by this project. Dubbed 'Genetic Profiling', the purpose of the mechanism was to take pre-recorded performances demonstrated by real people and recombine the stored decision-making and action data into multiple novel behaviour-sets. Artificial behaviour-sets generated by the new mechanism could then be used in controller software for NPCs, which may be represented in an environment by some form of avatar, or alternatively adopt a more agent-like omnipresence.

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The research performed by this project has largely focussed on the NPCs commonly found in computer games and other recreational virtual worlds. However, artificial behaviour-sets generated by Genetic Profiling mechanism could also potentially be applied to other areas of Computer Science. For example, in research projects involving Intelligent Environments, Genetic Profiling could potentially be used to generate a large number of synthetic evaluation participants, each providing different anthropomorphically realistic interaction performances [7]. To illustrate this further, the research presented in this paper outlines results from an investigation evaluating the anthropomorphism of artificial Genetic Profiling behaviour-sets, designed for NPCs inhabiting an intelligent household environment. During this experiment an amalgamated collection of real behavioural data was gathered from multiple different sources, including a combination of physical, virtual and mixed reality intelligent environments, each depicting a household scenario.

Following this introduction is a brief overview the theory behind this research, including a description of how assigning synthetic representations of human Personalities to NPCs can potentially increase the realism of their behaviour patterns. Following this the Genetic Profiling concept is presented, accompanied by an outline of how the mechanism can be used to generate artificial Personalities suitable for NPCs featured in computer game scenarios. Following a description of the different iWorlds (Information Worlds) used to gather behavioural data from real people, the methodology and results obtained from the Genetic Profiling anthropomorphism evaluation are then presented. Finally, an analysis is provided, detailing the key observations and conclusions made by this project.

1. Background Information

1.1. Generating Artificial Personalities for NPCs

To allow NPCs to exhibit behavioural performances more similar those of real humans, the Genetic Profiling mechanism was designed to generate rudimentary artificial Personalities to be used as decision-makers in controllers. Each Personality contained a number of behaviour-sets appropriate to represent each aspect of an NPC's role within the context of a scenario or environment. Although several different theories, models and approaches exist to describe the actual structure, content and origins of human Personalities, the general consensus from a psychological perspective is that they serve to impose influences upon individuals, constantly affecting their decision-making and actions [12, 13]. Several computer games and other Computer Science research projects have attempted to replicate this functionality, often by creating collections of weights to represent different characteristics or traits present within individual characters. Depending upon the approach taken, such a system could be as simple as assigning different values to a set of attributes common to every NPC in a world. Another possible strategy might be to select a personal subset of characteristics from a larger collection for each individual. In either case, the values of the variables would likely be applied to some mathematical calculation then used to add biases when deciding upon a behavioural response for any encountered stimuli. However, although such implementations may be capable of allowing NPCs to give reasonable performances, the behavioural patterns they demonstrate might not necessarily be representative of typical anthropomorphic behaviour.

Any lack of anthropomorphism in an NPC performance may be partly due to the fact that their Personality isn't the only source of influence potentially acting upon an individual during any given moment. An important factor to consider is that according to Psychology, once developed, the influences exhibited by a Personality on an individual will remain largely constant. For instance, a kind person will always behave in a kindly manner and can be expected to exhibit this characteristic to some extent in all of their chosen actions. Therefore, from Computer Science perspective it may be simpler to consider a Personality as a representation of the default model for a specific individual. However, there are many additional factors, not directly connected with an individual's Personality or mental state, which may also play a significant role in any decision-making process. For example, there could be internal attributes related to the current physical state of an individual, (e.g. are they ill, bored, hungry, tired, etc.). Likewise, influences could also originate from external sources, which could be manmade, (e.g. the content or layout of an environment), or perhaps the result of natural events, (e.g. weather conditions). Furthermore, a significant number of these additional influences may be completely unknown or unidentifiable even by the individuals themselves, possibly emerging from deep within their own sub-conscious, or as undetectable background noise within an environment. Whether directly relevant to a specific scenario or not these influences still act upon individuals in a similar manner to their inbuilt Personalities. These factors all play a combined role in the decision-making process, eventually leading to an action being selected from a range of possible options. There could also be instances where some over-lapping might occur between characteristics contained within a Personality and other unrelated influences. Therefore, such influences should not be ignored by an NPC decision-making system.

1.2. A Mimicked Approach

One potential approach allowing the effects contributed by known or unidentified internal and external influences in a scenario to be taken into account was to use Mimicry. In other words, a logging system simply records actions demonstrated by real people which are subsequently replayed by NPCs. Alternatively, rather than using Mimicry to simply copy the performance of a real person in its entirety, the strategy can also be designed to create behavioural fragments, (i.e. the individual actions). These fragments could potentially be later recombined into more complex behaviours. For example, in 2000, a signal processing research project led by Kenmochi Hideki, developed voice synthesizer software replicating human singing performances [2]. This software used as the base for *Vocaloid* (Yamaha Corporation, 2004), which used pre-recorded phonic samples mimicked from real voice actors to generate artificial sounds, (i.e. singing or other verbal performances) [11].

1.3. An Evolutionary Approach

Another possible means of generating anthropomorphically realistic behaviour-sets would be to use an evolutionary approach to create NPC controllers in a pseudo-natural manner. Evolutionary Algorithms form an area of Computer Science, encompassing numerous Artificial Intelligence mechanisms, each designed to evolve solutions to problems using approaches largely inspired by Darwinian Natural Selection. For example, Genetic Algorithms were used by the Gershwyn project to research artificial creativity in song writing [15]. Learning Classifier Systems were used by Priesterjahn

et al, to generate rules for their reactive virtual boxing NPC controller, [14]. Finally, Karl Sims used Genetic Programming to evolve several virtual creatures inhabiting several environments, simulating land and ocean-based ecosystems [16].

Some of the examples describing Evolutionary Algorithms projects can also be classified into another area of Computer Science research, specifically Artificial Life. For example, John Horton Conway's 'Game of Life' demonstrated two-dimensional Cellular Automata, where users created the initial pattern of a universe then watched as it evolved over time, spawning different representations of synthetic life [9]. The Avida Artificial Life system took a similar approach, using a population of strings containing machine-language-style instructions, known as genomes [1]. The benefits of placing an emphasis on replicating various natural biological processes for NPC controllers have been demonstrated by numerous other Computer Science projects, including implementations used in past commercial computer games. For example in *Creatures* (Millennium Interactive, 1996), Artificial Neural Networks were used to replicate an entire physiological system [10].

1.4. So which approach is best?

When it comes to portraying realistic representations of real human behaviours Mimicry is a cost-effective method that is almost always guaranteed to produce useful results. After all, if avatars are replaying actions previously demonstrated by real people, this grounding alone should be sufficient to ensure an anthropomorphic behavioural performance. However, Mimicry is by no means a perfect system. In addition to difficulties identifying influence sources such as those discussed earlier, adopting a purely Mimicry-based approach when implementing NPC controllers could potentially result in countless perfectly acceptable actions present in scenarios simply being ignored, as they were not performed in any of the recorded behaviour-sets.

Unfortunately the situation doesn't look much better from an evolutionary perspective. For starters, to a large extent both Evolutionary Algorithms and Artificial Life systems require a description of all the possible actions that could potentially be performed and influences present prior to the start of a session. Identifying all these possibilities could be challenging and time-consuming for programmers, especially in complex scenarios and environments. Another issue with an evolutionary-based approach is that unlike Mimicry any possible action that could be performed by an NPC may be chosen at some point. While this does potentially permit new ad hoc behaviour generation, there is no guarantee that the action patterns would resemble decision-making exhibited by real people when in similar circumstances.

2. Genetic Profiling

To achieve the aims of this project, a new Artificial Intelligence mechanism was required, which could allow the anthropomorphic grounding obtained from mimicked data to be combined with the artificial variation produced by Evolutionary Algorithms and Artificial Life systems. Consequently this led to the creation of the Genetic Profiling mechanism, which combines elements of Mimicry with an evolutionary-based approach, initially inspired by techniques used in Genetic Programming. The Genetic Profiling mechanism was designed to be easily customisable to suit a variety of different scenarios. Many traditional Evolutionary Algorithms typically require

advanced knowledge of any possible actions and functions that can be used to create behaviours. However, thanks to a Mimicry-based profiling system Genetic Profiling can dispense with this requirement, with possible options simply being discovered by the system during a session, allowing new behaviours to naturally emerge.

2.1. Implementation Strategies

Two different implementation strategies were devised for the Genetic Profiling mechanism. The following is a brief overview of each method.

2.1.1. Benchmark Genetic Profiling

The first implementation strategy was dubbed 'Benchmark Genetic Profiling'. At the start of each session the mechanism selected a single Mimicry Profile from the stored collection available to the system, to act as a benchmark. An initial population of randomly generated behaviour-sets were created by the evolutionary component. Each of these samples were subsequently tested for fitness and ranked based upon how similar in structure they were to the content stored in the selected benchmark.

Subsequent generations of samples were created by applying genetic operators (i.e. crossover, mutation and reproduction) to samples selected from the previous population using a Fitness Proportional Selection method. During the fitness evaluation process, Artificial Profiles with a higher or lower number of behaviours than the benchmark Mimicry Profile were penalised. This measure was taken to ensure behaviour-sets similar in size to the mimicked benchmark would be returned by the system.

2.1.2. Direct Genetic Profiling

The second implementation strategy was dubbed 'Direct Genetic Profiling'. When a session commenced, the initial population of samples were created by randomly selecting Mimicry Profiles from the available collection. It was possible for the same Mimicry Profile to be selected for multiple samples, especially if the collection was smaller than the required population size. This initial population then had the genetic operators from the evolution component of the mechanism, (i.e. crossover, mutation and reproduction) applied directly to the content of their behaviour-sets.

By using the actual mimicked data for an initial collection of Artificial Profiles, the mechanism can directly pass on fragments of anthropomorphic behavioural patterns, as demonstrated by real humans, to samples in subsequent generations. Implementation of the fitness measure in the Direct Method was more bespoke than that of the Benchmark Method, as the anthropomorphic properties of Artificial Profiles required grounding appropriate to the environment or scenario being used. Typically, the fitness was calculated by comparing differences in magnitude of delta values for pairs of adjacent behaviours in the artificial sets. The theory behind this approach was that by assigning better fitness values to Profiles with the smallest differences between adjacent actions, unrealistic behaviours created by combining content from several different sets together could be avoided.

2.2. Artificial Personality Representation

The Genetic Profiling mechanism was designed to create individual behaviour-sets based upon the anthropomorphic action patterns mimicked from real people. However,

when creating artificial Personalities for NPCs, it is possible to combine several Genetic Profiling behaviour-sets to stage even more complex performances. This could potentially allow NPCs to adapt to changes in their current environment. For example, many real people might behave entirely differently in a working environment, compared to how they act back in the privacy of their own home.

Essentially, from the perspective of this project, an artificial Personality can contain a single or multiple behaviour-sets, which in turn each include one or more behaviours (i.e. actions) representing decision-making. Behaviour-sets created from several different scenarios or environments can be represented in a single Personality as different Personae. Each Persona is comprised from one or more behaviour-sets created by performances in the same environment or scenario. Personae containing multiple behaviour-sets can potentially be used to allow NPCs to exhibit behavioural changes occurring during long-term performances, (e.g. different days of a week). This can also potentially prevent them from giving repetitive or predictable performances, which may appear non-anthropomorphic to observers.

3. Evaluating NPC Anthropomorphism

3.1. iWorld Environments

The iWorld concept, discussed in several of this project's earlier papers, [6, 8] was applied to this investigation. Several iWorlds each modelling a similar intelligent household, were implemented specifically to observe and record inhabitant behaviours when interacting with the environment, generating a collection of mimicry data.

3.1.1. A Physical Intelligent Environment

The first iWorld used to gather mimicry data from evaluation participants was provided by the University of Essex iSpace, a purpose-built self-contained intelligent building, designed to resemble a typical household environment [3]. To aid the discreet deployment of a large network of embedded sensors, intelligent devices and other technologies, panels concealing hollow walls and ceilings were incorporated into each room's design. Being an intelligent environment, all the smart-devices featured in the iSpace were linked with a single network, controllable and observable via computer code, using a series of inbuilt OSGI UPnP wrapper methods.

3.1.2. A Mixed Reality Intelligent Environment

Mixed Reality has also been used in a number of Pervasive Computer Science projects, such as those allowing devices or other features in intelligent environments to be remotely observed or controlled via simple GUI graphical interfaces or more complex virtual worlds [4, 6, 8]. To replicate this functionality another iWorld was created by augmenting the existing physical iSpace environment with a new bespoke virtual component. Figure 1 shows views of the physical and virtual components used in this iWorld design. In addition to cloning intelligent devices and augmenting static objects in the physical iSpace, entirely new smart technologies not present in the physical environment were added to the virtual component, increasing the range of actions that could be performed by inhabitants.

Figure 1. The Mixed Reality Intelligent Environment

3.1.3. A Virtual Intelligent Environment

Sessions recording mimicry data from participants using the physical and Mixed Reality iWorlds were performed in real-time and in a surrounding that realistically represented the scenario and intended context. Interaction involved participants manually using devices, demonstrating realistic anthropomorphic behavioural patterns. However, a third option was also available, potentially allowing anthropomorphic behaviours to be observed without the need for real-time experimentation sessions.

Taking inspiration from the Artificial Intelligence systems used by some existing commercial computer games, such as *The Sims* (Maxis / EA Games, 2000), the final iWorld, (shown in Figure 2) assigned four 'Needs' variables to each session participant, (i.e. Boredom, Hunger, Hygiene and Tiredness). These variables were intended to represent some rudimentary states common to all real people and were used to create specific stimuli, prompting behavioural responses from participants.

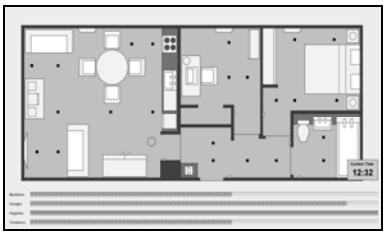

Figure 2. The Virtual Household Game Environment

3.2. Evaluation Strategy

3.2.1. Generating Mimicry Profiles

As this project was mainly interested in generating NPCs for use in computer games, it was desirable to encourage behaviour-sets containing interesting, (i.e. active) performances to be selected by the Genetic Profiling mechanism more frequently. Consequently, approximately ninety percent of the final collection of mimicry profiles used during the evaluation was generated by the Virtual Household Game Environment. The remainder of the mimicry collection was provided by the two other iWorld systems. By using this disproportionate ratio it was possible to significantly influence the general style of many subsequent artificial behaviour-sets generated by the Genetic Profiling mechanism. However, the grounded anthropomorphic behaviour-patterns gathered in the other iWorlds still provided significant contributions when selected by the crossover or mutation genetic operators. To suit other Intelligent Environments or Cloud of Things related projects, the ratio could potentially be adjusted to place greater emphasis on the mimicked data generated in the physical or Mixed Reality iWorlds.

3.2.2. Assessing NPC Anthropomorphism

Unlike the experimentation strategies used in other investigations from this project, a slightly different approach was adopted for this evaluation. Rather than presenting participants with a graphical representation of different NPC performances, this evaluation chose to concentrate on the content of the generated behavioural patterns themselves. During each experiment session, evaluation participants were presented with images of four different behaviour-sets. Three of the sets displayed unmodified Mimicry Profiles, generated in the investigation iWorlds. The single remaining sample was generated using one of the Genetic Profiling implementations. Evaluation participants were simply asked to identify which of the behaviour-sets they believed had been generated by an Artificial Intelligence.

Inspired by the methodology used for the Turing Test analysis [5, 17], the intention of this experiment was to assess whether Genetic Profiling behaviour-sets could successfully fool people into believing they were created by the actions of real individuals. The theory was that even minor inaccuracies in the content or pattern structure of a behaviour-set would attract attention from any observer when compared with similar data-sets obtained from real people. If no noticeable imperfections were present then the artificial behaviour-set could be considered similar to the Mimicry Profiles. Hence any NPC performances should appear to be anthropomorphic in style.

3.3. Evaluation Results

3.3.1. Benchmark Genetic Profiling

The experiment assessing the potential anthropomorphism of behaviour-sets generated by Benchmark Genetic Profiling presented participants with the four Profile designs shown in Figure 3. No time limit was imposed on how long a participant could observe the behaviour-sets, which were all displayed onscreen simultaneously. The experiment informed participants that three of the behaviour-sets were created by recording the actions of real people in a household environment, while the one remaining Profile had been generated by an Artificial Intelligence system. When they were ready participants were simply asked to try and identify which of the four behaviour-sets they believed had been generated by the Artificial Intelligence system. Table 1 presents the choices made by the participants during their respective sessions. For clarity, the correct answer to this question, (i.e. the behaviour-set generated by the Benchmark Genetic Profiling implementation) is highlighted in grey.

The results obtained from the first experiment, shown in Table 1, strongly indicated that the artificial behaviour-set generated by the Benchmark Genetic Profiling implementation was capable of appearing anthropomorphic, when directly compared with real human performances. Attracting approximately one-fifth of the recorded votes, (significantly below the twenty-five percent average threshold), the Artificial Profile appears to have successfully fooled a large majority of the evaluation participants. Indeed the Genetic Profiling behaviour-set actually scored fewer votes than two of the three Mimicry Profiles used in the experiment.

1	09:46	Computer
2	10:32	Oven
3	12:59	Kitchen Sink
4	14:54	Sofa 2
5	16:20	Television 1
6	18:13	Oven
7	19:42	Bath
8	21:50	Bed

1	10:41	Chair 3
2	12:15	Stereo
3	13:53	Refrigerator
4	16:32	Bath
5	19:02	Sofa 2
6	20:04	Television 1
7	21:08	Oven
8	22:31	Bed

1	09:58	Chair 5
2	10:38	Computer
3	12:17	Refrigerator
4	13:35	Toilet
5	14:33	Sofa 2
6	16:44	Television 1
7	17:47	Oven
8	18:50	Kitchen Sink
9	21:03	Chair 2
10	22:14	Television 1
11	23:31	Bed

1	09:13	Sofa 1
2	10:12	Television 1
3	11:10	Refrigerator
4	11:35	Kitchen Sink
5	12:52	Sofa 2
6	13:39	Stereo
7	14:09	Oven
8	15:22	Bath
9	16:06	Chair 5
10	16:32	Computer
11	18:03	Oven
12	18:48	Bathroom Sink
13	19:07	Bath
14	19:35	Bed

Figure 3. Mimicry & Benchmark Genetic Profiling Behaviour-Sets

Table 1. Benchmark Genetic Profiling Evaluation Results

Instance	Number Selected	Percentage Selected
Top-Left Table	12	18.8%
Top-Right Table	29	45.3%
Bottom-Left Table	16	25%
Bottom-Right Table	7	10.9%

3.3.2. Direct Genetic Profiling

The same strategy used in the first experiment was applied when evaluating the potential anthropomorphism of performances exhibited from behaviour-sets generated by the Direct Genetic Profiling implementation. Figure 4 shows the four behaviour-set designs presented to the evaluation participants. As in the first experiment, three of the behaviour-sets were unmodified Mimicry Profiles. The one remaining behaviour-set was generated using the Direct Genetic Profiling implementation. The distribution of votes obtained from the participants of this experiment is shown in Table 2. As before, for clarity the correct answer to this question was the table option highlighted in grey.

In this instance the Direct Genetic Profiling implementation attracted slightly more correct identifications from participants than the associated Mimicry Profiles. However, as shown by the results, approximately 70% of the evaluation participants were successfully fooled by the presented Artificial Profile, suggesting many would consider a NPC demonstrating that behaviour-set to be giving a realistically anthropomorphic performance. Furthermore, there was an even split of the scores obtained by the three Mimicry Profiles and all four sets of votes were close to the twenty-five percent average. Based upon probability, this pattern could potentially suggest that many of the participants may have simply been randomly guessing when making their selections during this experiment. Therefore, the ability of Direct Genetic Profiling to generate anthropomorphic behaviour-sets similar to those generated by real people may actually be even better than indicated by the results in Table 2.

1	10:41	Stereo
2	12:59	Oven
3	14:50	Kitchen Sink
4	15:51	Sofa 2
5	17:59	Bath
6	19:49	Sofa 2
7	20:16	Television 1
8	21:30	Oven
9	23:17	Bed

1	09:34	Sofa 2
2	11:01	Television 1
3	13:05	Oven
4	14:30	Toilet
5	16:48	Sofa 2
6	18:22	Refrigerator
7	20:07	Television 1
8	21:09	Bath
9	22:42	Bed

1	09:46	Computer
2	10:31	Oven
3	12:59	Kitchen Sink
4	14:55	Sofa 2
5	16:19	Television 1
6	18:12	Oven
7	19:43	Bath
8	21:49	Bed

1	09:58	Chair 5
2	10:38	Computer
3	13:53	Refrigerator
4	16:32	Bath
5	19:02	Sofa 2
6	20:04	Television 1
7	21:08	Oven
8	21:49	Bed

Figure 4. Mimicry & Direct Genetic Profiling Behaviour-Sets

Table 2. Direct Genetic Profiling Evaluation Results

Instance	Number Selected	Percentage Selected
Top-Left Table	15	23.4%
Top-Right Table	15	23.4%
Bottom-Left Table	15	23.4%
Bottom-Right Table	19	29.7%

3.4. Experimentation Strategy Discussion

In its past evaluations this project has typically used an iWorld as a demonstration platform to present actual NPCs, (typically represented using avatars), giving real-time performances to participants. However, this investigation chose to take a slightly different approach. One of the reasons behind this new evaluation strategy was a necessity due to the resources available to this project. From a household environment context, many of the actions performed by inhabitants involved sitting around in one location for potentially long intervals. If they were to appear anthropomorphic, this was still a necessary element of an NPC's performance even after adopting a more computer game, (i.e. active) behavioural style. However, it simply wasn't possible for this project to implement a bespoke demonstration iWorld capable of effectively portraying behaviours, such as eating, which would have required NPCs to manipulate minor objects over sustained periods. It was felt likely that any produced presentation could potentially induce confusion from any uninformed audience during an evaluation, which may have distorted the obtained results. While this limitation wasn't a problem when gathering data for Mimicry Profiles, (as avatars weren't used in the iWorlds for this investigation), the concern was that evaluation participants may confuse the graphical restrictions of exhibited actions performed by NPC avatars as evidence of non-anthropomorphic behaviour. By removing the graphical component from the actual experiments, it was hoped that the context of the investigation could be kept in focus amongst participants, preventing the distortion of obtained results. Effectively, this experiment asked people use their own imaginations to visualise the performances given by NPC avatars following each of the presented sets of behaviours.

4. CONCLUSIONS

4.1. Summary & Research Findings

This paper has presented an introduction to a new Artificial Intelligence mechanism 'Genetic Profiling', designed primarily to encourage realistic anthropomorphic behaviours, (i.e. decision-making and actions) to be performed by NPCs (computer-controlled representations of humans) in computer games and other contexts. The investigation reviewed in this paper demonstrates how mimicked data obtained from a large number of people, using several different source environments, could be combined to allow the generation of useful artificial behaviour-sets, focused towards an intended purpose. In this example that purpose was for use in the controllers of computer game NPCs, but the same methodology could also be applied to generate behaviour-sets suitable for other Computer Science research areas. Indeed, two of the three iWorlds used to supply mimicry data during this investigation made use of a full-scale physical Intelligent Environment, which could have also been used to playback artificial Genetic Profiling behaviour-sets stored in generated NPC controllers.

A description of the internal architecture of the Genetic Profiling mechanism has been provided, describing how naturally anthropomorphic behaviours can be mimicked from real people and subsequently applied to an evolutionary process to create multiple new artificial behaviour-sets. Also highlighted was a new model describing how one or more of the artificial behaviour-sets generated by Genetic Profiling could potentially be structured to create replica human Personalities, designed for NPC controllers.

Finally, the evaluation procedure used by this investigation to assess the potential levels of anthropomorphism obtainable from artificial behaviour-sets generated by Genetic Profiling implementations was presented. The iWorlds used to gather the initial mimicry behaviour-sets for the system were outlined, each based upon a typical Intelligent Environment architecture. Also described was the new evaluation strategy, partially inspired by the Turing Test, which was used to assess whether artificial Genetic Profiling behaviour-sets could fool people into believing they were representing the behavioural patterns of real individuals.

Two separate experiments were performed to evaluate each of the potential Genetic Profiling implementation strategies. Overall, the results obtained from the sessions performed in each experiment provided some encouraging results from the perspective of this project's research focus. Both the Benchmark and Direct Genetic Profiling implementation strategies demonstrated that behaviour-sets generated by either method were able to successfully fool a significant majority of evaluation participants into believing they represented actions performed by real people. By successfully concealing the Artificial Profiles amongst a collection of behaviour-sets created by mimicking the behaviours of real people, there is a strong indication of anthropomorphism in the generated content. Therefore, NPCs using one or more of the generated behaviour-sets in artificial Personalities should be exhibiting a strong level of anthropomorphism from their decision-making and any subsequent actions performed.

4.2. The Next Step

The next phase of this project will see the Genetic Profiling mechanism being applied to NPCs performing different roles in various computer game-based environments. Internet-based computer games, attracting millions of players, who access common

virtual worlds to play remotely, will be explored further. Massive Multiuser Online worlds like these may potentially offer an abundance of anthropomorphic mimicry data.

Another area to be explored is how Genetic Profiling can be applied to suit the different uses of NPCs in computer games. Many are used to provide competitive opponents to challenge, while others might fight alongside the real players as support characters. Some games use NPCs simply as background characters to increase the immersion presented by a virtual environment, while others can use them simply to provide information crucial for advancing an ongoing plotline. This project hopes to investigate whether the Genetic Profiling mechanism can be applied to each of the identified NPC types in a variety of different scenarios, in each case attempting to increase the anthropomorphism in their performances, to make their behaviour appear more similar to that of real human players. Evaluations comparing each version of Genetic Profiling with other potential NPC Artificial Intelligence mechanisms will also be staged during this phase.

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