Interactive Evolution as a game mechanic

Interaktiv Evolution som en spelmekanik

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Abstract. This thesis explores how interactive evolution is perceived as a game mechanic in a simulation based environment. An artifact called Genetic Olympics was created as a simulation in which interactive evolution was implemented. In the artifact, users are presented with activities that allow AI-agents, in the form of Olympians, to compete against each other. The user functions as the selection part of an evolutionary algorithm, letting the user choose the direction to evolve the Olympians by continually breeding them in different ways. Data about how users perceived interactive evolution as a game mechanic was gathered through interviews. The data from the interviews later formed a questionnaire. The answers from the questionnaire showed how the users had both positive and negative experiences when using the artifact. The users proposed how to augment the artifact to become more like a game. By adding minor goals for the user to reach, the artifact could lean more toward what a game resembles. All in all, the data shows that interactive evolution works in simulation based games.

Keywords: Interactive evolution, Casual Creators, Explorative, Design Science, Simulation game

1. Introduction

In today’s game development, computers can be assigned to tasks that designers would otherwise have done. The computers can also be used to help designers with the creative process e.g. map generation [1], animations [2], and more. These tools lie in the category of Procedural Content Generation (PCG) [2]. PCG uses artificial intelligence to create different types of game content. An example of a PCG-tool is Ropossum [3], where a designer creates a level for the game Cut the Rope [4]. If the level is unplayable, it gives examples on how it can be altered to make it playable.

In PCG there are many different techniques, one of which is called Mixed-Initiative (MI). MI is where a computer and a human collaborate in order to make content [2]. There are two types of tools that are categorized under the name MI. The first type of tool is Computer Aided Design (CAD). An example of CAD is the earlier mentioned Ropossum where the human creates the content and the computer evaluates it. The second type of tool is called interactive evolution (IE) [2]. IE is where a computer creates the content and the human evaluates it.

Interactive evolution has been used in games outside of development. In Galactic Arms Race (GAR) [5], it generates content in form of weapons and upgrades and adapts them to what the player preferred in the past, in order to create new content based on them. The players in GAR are never aware of the underlying IE. However, in the program Picbreeder [6], the users directly affects the interactive evolution by choosing pictures that appeals to them and the program creates new pictures based on the users choice. Directly controlled interactive evolution is often used in tools rather than as a game mechanic [6] [7] [8].

The purpose of this study is therefore to explore how the user perceives interactive evolution as a game mechanic in a simulation based environment. A simulation based environment is chosen because of its similarities with IE, e.g. open ended structure [9] and indirect control [10]. When implementing IE in a system, Compton et al. proposes a design space called Casual Creators [11]. The Casual Creators methodology focuses on making design as an intrinsically pleasurable activity. This
provides the user with the freedom of designing without a goal. This also fits well with the nature of simulation based games, where the user can play simply for the activity the game provides [9].

To make this possible, we will use design science [12] because it synergizes well with the iterative nature of game development. However, due to the scarcity of research about this problem area, this study’s approach will be explorative. To get a better grasp about the problem area, we will set up semi-structured interviews [13] in order to later form a questionnaire. The questionnaire will function as our main source of data.

By learning what users think about interactive evolution as a game mechanic in a simulation based environment, we hope to give a better understanding of how interactive evolution can be used in games. When following the Casual Creators methodology to create an artifact, we can also see the strengths and weaknesses of the proposed design patterns.

In the background section we will further explain about the above mentioned examples and terms. We are also going to bring up the definition of fun and other relevant information regarding the problem area.

2. Background
To better understand the problem area, an explanation is provided on each of the relevant subjects.

2.1 Genetic algorithm
Evolutionary algorithms mimic natural selection [14]. A genetic algorithm is an evolutionary algorithm in which individuals have a fixed size. It is often used for solving a problem by using techniques from evolution itself such as selection, mutation and various types of crossover-methods [15]. Genetic algorithms are often used in procedural content generation (PCG). PCG allows for content to be created procedurally with limited user input as opposed to creating it manually. The different PCG-methods are used for a number of reasons, e.g. saving development costs, allowing games to become adaptive, and aiding designers to be creative [2].

Genetic algorithms starts off with a population of randomly generated individuals represented as strings, each containing values that are connected to solving the problem. The evolution strategy (ES) can be represented as \( \mu + \lambda \). The parameter \( \mu \) characterizes the population's elite that are kept between generations and the parameter \( \lambda \) represents the reproduced generation [2] [15]. The individuals in the population will perform their task and be evaluated by an evaluation function (EF). The EF will rate the individuals depending on their performance and the rating is called fitness value. The EF is custom designed for the specific problem you are trying to solve. It must be fast and efficient because of its extensive usage [16]. When all individuals have been rated, they are sorted by ascending fitness value. To determine the \( \mu \) the use of a selection method is applied e.g. Roulette-Wheel Selection and Tournament Selection [15].

A selection technique can be explained as: Remove the \( \lambda \) and substitute them with copies of the remaining \( \mu \) individuals, called the offspring. The offspring is created through a crossover technique. Crossover is the stage in the genetic algorithm where pairs of \( \mu \) individuals genes are mixed, forming the new generation of individuals. There are many different types of crossover methods, each with their strengths and weaknesses. Learning what type of technique fits a problem becomes a matter of
testing [17] [15]. After the crossover process is completed, there is a chance that mutation will occur if chosen to be implemented. The mutation can e.g. affect the genes by an offset value [2]. For an in-depth explanation about this type of algorithm in games, Brian Schwab explains it thoroughly [15].

2.2 Interactive evolution

Mixed-initiative is a technique in PCG where the human and the computer collaborate in order to create content [2] [18] [19]. There are two general ways of thinking about a mixed-initiative approach. One is where the human creates the content and lets the computer come up with suggestions or give feedback: called computer-aided design [2]. The other method is called interactive evolution in which the computer creates the content and the human acts as the evaluator [2].

Interactive evolution has been used for creating various types of programs and tools to facilitate the development and design process. In game development they are often used for helping with level design, e.g. Rapossum [3] [20]. Interactive evolution has also been used in programs such as Picbreeder [6] where the focus is solely on creativity.

There are systems that have used Interactive evolution in different ways, both as creative tools, and games. To understand its area of use, we present a few examples.

- **Picbreeder** is an online service that allows users to collaboratively evolve images. Users are presented with 15 images and select the ones that appeal to them. The selected image(s) produces the new generation. This enables all types of users to; regardless of their skill or talent, participate in the creative and exploratory process. Picbreeder also has an online community where users can share their images and let other users continue to evolve them [21] [6].

- **Petalz** is an online social game on Facebook. The game revolves around planting seeds and breeding unique flowers to store in your collection. The user possesses flower pots in which they plant the flower seeds. When the seeds have grown into flowers, if the user clicks on a flower, he or she is presented a few different options. The user can: pollinate the flower, cross-pollinate two flowers, share a flower with a friend, sell the flower on the marketplace for virtual currency, etc. [22].

- **Spore** is a game where evolution is the main focus. It lets the player evolve a single cell organism all the way to a space traveling species. It is a procedurally generated, open-ended game. There are five stages in the game that the players go through, the cell-stage, creature-stage, tribal stage, civilization stage and the space stage. Each stage works differently in terms of playstyle but the focus still lies in evolving your creature. Spore also has a community that lets you share your creations with other players using the Spore API. The creatures/buildings/vehicles are saved into a DNA-string and stored in a database where they can be automatically added to some other player’s world [23].

- **Galactic Arms Race** is a game where you pilot a gunship in a galaxy. Your mission is to defeat aliens and progress your gunship by picking up weapons and upgrades. Weapons are generated through a *Neuro Evolution of Augmenting Topologies* (NEAT), a content-generation technology. The unique aspect of the NEAT is how it adapts its generated content based on what weapons and upgrades the player preferred in the past, and also creates new weapons based on them [5].
2.4 Casual creators

John S. Gero implies that design is an activity that is goal-oriented, intentional and purpose-driven [24]. There is a difference between designing a product for a company versus design as an autotelic activity [11]. Kate Compton and Michael Mateas propose an alternative design space as an intrinsically pleasurable activity rather than as an extrinsically-motivated way to accomplish tasks. They call their design space Casual Creators [11] and define it as:

“Interactive evolution that encourages the fast, confident, and pleasurable exploration of a possibility space, resulting in the creation or discovery of surprising new artifacts that bring feelings of pride, ownership, and creativity to the users that make them.”

For designing Casual Creators, there are design patterns [25] that can be kept in mind, such as: Instant Feedback, Entertaining Evaluations, and No Blank Canvas, etc. For a further explanation of the design patterns proposed in the Casual Creators methodology, see Table 1.

Table 1 Design patterns from Casual Creators

<table>
<thead>
<tr>
<th>Design Pattern</th>
<th>Description</th>
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<tbody>
<tr>
<td>Instant Feedback</td>
<td>Every time a user wants to make a change to the artifact being made, it must be instantaneously shown to the user. It is important for the user to see the results of their changes, eventually leading the user to master the system while iterating over the artifact [11]. One method of instant feedback called the chorus line implies that instead of creating one artifact, the system generates multiple artifacts for the user. This enables the user to spot the subtle differences of an artifact [11].</td>
</tr>
<tr>
<td>Entertaining Evaluations</td>
<td>In the game Spore [23] there is a creature creator that when modifying the creatures, the creature responds by showing emotions e.g. laughing and cheering. This is particularly useful for letting the user feel pride by the choices made. It can also provide help if the user has a hard time knowing which design direction to take. Therefore a simulated guide can be present to steer the user to a path if they choose to [11].</td>
</tr>
<tr>
<td>No blank canvas</td>
<td>When using a creativity tool for the first time, the user can become intimidated. Especially if the user starts with nothing but a massive amount of different choices. The best way to solve this issue is to give the user something to play around with from the start, it hardly matters what it is. The first decision is often the hardest, so making that decision for the user, removes the fear of starting from scratch [11] [26]. This design pattern is used in Spore [23], where the player begins with a starting shape.</td>
</tr>
<tr>
<td>Limiting actions to encourage exploration</td>
<td>While removing the intimidating first decision, there is also a good practice to make every decision meaningful and to some degree limit the amount of decisions the player can make [11] [21].</td>
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</tbody>
</table>
Mutant Shopping

Instead of letting the user create the content using a creative tool handed to them through a system, the user is instead presented with similar looking artifacts to choose from. This is similar to how Picbreeder [6] works where the user navigates the possibility space by picking one of the new options presented. This process has a lot in common with interactive evolution. Mutant shopping has its focus on discovering new and unexpected artifacts, rather than evolving the best and most optimal artifact for solving a specific problem [2] [11] [14].

Saving and sharing

By letting the user easily share their creations on community websites, it may encourage other users to design new grounds or simply learning from each other. This gives your creations substantial meaning, making the creator feel encouraged and proud of their produced artifact [11] [6] [21].

2.5 Direct control- vs. indirect control-schemes

Direct control is a type of control scheme where the player controls an avatar using a joystick/d-pad and the motion of the joystick directly translates to the movement of the avatar [27] [28]. Indirect control is when the motion is not directly translated. An example of this can be taken from old adventure games where the user points and clicks at different locations and the avatar moves to the location accordingly, if the location is traversable [29]. If the avatar cannot move there, they usually notify the user. This can create a depth to the controlled avatar instead of the user being full in control [10]. A genre of games that often uses indirect control schemes, are simulation games.

2.6 Simulation games

Marc Prensky [30] mentions that the definition of simulation ranges from:

- Any synthetic or counterfeit creation
- The creation of an artificial world which approximates the real one
- Something that creates the reality of the workplace (or whatever place)

If an object (real or virtual) “simulates” something, it is a simulation. This goes for toys, stories, and games. He points out that simulations themselves are not games but rather tools. For a simulation to become a game, they require certain elements, such as: fun, play, rules, winning, etc. [30]. Examples of simulation based games are: Farming Simulator Series [31], Harvest Moon [28], Arma Series [27] and Microsoft Flight Simulator X [32]. Maximum Games brings up some thoughts why these kinds of games are addictive and fun:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>Open-ended structure</td>
<td>The players set their own goals and therefore making each play-through a different experience [9].</td>
</tr>
<tr>
<td>Multiple routes</td>
<td>There is not a single linear path that the player follows to reach the end. This gives the player a choice of freedom to walk their own path [9].</td>
</tr>
<tr>
<td>Repetition</td>
<td>Repetition creates a soothing and rewarding atmosphere. The player feels good when they know what to do. Repetition calms the players, leading them into a pattern that can resemble work. The players find satisfaction in reaping the rewards of their hard work [9].</td>
</tr>
</tbody>
</table>
2.7 Definition of fun in games

Fun is a subjective term and there are many different definitions of what fun is. Jesse Schell’s definition is pleasure with surprises [33] and Raph Koster defines it as the act of mastering a problem mentally [34].

What some people call fun, others might think of it as a chore. When creating a game, there is some ground rules you can follow to make your game more “fun”. Tom Francis points out that one of the key aspects of making a good game is freedom and defines it as: The extent to which a game reacts to your choices with interesting results [35]. The game needs to have interesting responses to the player’s actions, not just a huge game world with low interaction. Another point that Tom Francis mentions is the importance of game feel. Every interaction should try to be convincing and pleasurable. Challenge is also a universal way of thinking of games, without challenge there is no reason for the players to continue playing [35].

When creating a game, there are a lot of ways to design them to be fun. Koster mentions that different games will appeal to different types of people, and that there is no correct answer to making a game “fun” [34].

3. Purpose

Interactive evolution in programs like Picbreeder [6] and Petalz [22] is used for designing artifacts and making the creative process easy for users, regardless of skill. Casual Creators [11] aim towards making a support tool for autotelic creativity rather than task-focused creativity. We therefore propose to take it one step further. By using interactive evolution in a way that allows the user to not only create artifacts for their own enjoyment but also a simulation to test the artifacts in various types of events. In Galactic Arms Race the user is indirectly controlling the interactive evolution whereas we want to explore the possibilities of using interactive evolution directly controlled. Similar to how it is used in most creative tools.

This gives the users the benefits of the Casual Creators design patterns but also lets the users if they want to, solve non-trivial problems by using the genetic algorithm approach. The artifact will let the user become part of the genetic algorithm, more specifically, the evaluation and selection methods. Simulation based games and interactive evolution in tools share similar properties. Therefore, by creating a simulation based game we can also validate our artifact to see how the implementation of interactive evolution is perceived within this genre of games.

3.1 Research question

“How do users perceive interactive evolution as a game mechanic in a simulation?”

3.2 Scope

Interactive evolution lets the human become the evaluator of the generated content. Because of this, there is no need for a fitness evaluation method. Therefore we will not mention the different techniques for creating such functionality.

When it comes to crossover methods, there are a lot of different ones to choose from e.g. one point crossover, uniform crossover, and arithmetic crossover [15] [17]. The crossover methods used in our artifact will be explained in the result.
In the *Casual Creators* [11] paper there are a few other design patterns that Compton et al. proposes. These patterns won't fill any purpose in our artifact because they focus more on creativity as a tool rather than a game mechanic. The artifact proposed in this thesis will not be a tool; instead it will resemble a toy. This will be discussed later in the method.

We will not mention our own definition of fun, instead we will relate to the definitions mentioned in section 2.7. We choose to not use our own definitions because fun is a subjective term, however, having a definition to lean on makes it easier to discuss.

4. Method

To learn more about the connection between simulation-based games and interactive evolution we propose an explorative research process. Even though interactive evolution has been used in games, e.g. GAR, the player is never aware that it exists. It is uncommon for Interactive evolution to be visible, directly controlled, and affecting a games state by the user’s choice. Therefore, due to the low amount of information regarding this problem area, our research will be explorative.

To find answers we will use the *Design Science* methodology which focuses on the development and performance of artifacts with intention of improving their functionality. The Design Science methodology advocates the iterative and incremental activity of design [12], and this synergizes well with the iterative nature of game development.

4.1 Research process

By following the design science methodology we aim to create an artifact and evaluate its core principles. We will follow the design process that Offermann et al. proposes in their paper *Outline of a Design Science Research Process* [36].

Exploratory research is to explore the research question without giving any concrete answers. The focus lies on getting a better understanding of the problem area. This approach is suitable for problems where earlier research is scarce [37].

4.1.1 Literature research

To get a better grasp of the problem area, information about similar projects must be looked into early on. Having the knowledge about the existing problems and their solutions makes it easier to create a new solution. This is the first step in the design science process but also the foundation of the entirety of this thesis.

The problem area we are working in is broad in terms of the wide spectrum of uses for it, as interactive evolution has been used in games (*Petalz, Spore*) as well as creative programs (*Picbreeder, Ropossum*). By searching for papers regarding the above mentioned games and programs, we gain knowledge of how implement interactive evolution. Information about simulation based games will also be looked into as well as PCG and genetic algorithms in general.

To find the information that we want, we will use Libsearch and Google Scholar because their vast amount of different content [38] [39]. Narrowing our search words is important to find relevant content. The search terms we will use are: *Genetic Algorithms, Procedural Content Generation, Interactive Evolution, Petalz, Picbreeder, Spore, Crossover methods, Design Patterns, Indirect control, Simulation games.*
4.1.2 Increased knowledge about the given problem

After our literature research we found a paper that proposed a new approach to the design process of using interactive evolution. The design space proposed is called Casual Creators and will be used as guidelines when creating the artifact. For our artifact to fall within the space of Casual Creators it needs to follow some of the design patterns stated in section 2.4 and furthermore in the paper Casual Creators [11] written by Compton et al.

The already existing systems that uses interactive evolution mentioned in section 2.2 were found by snowballing the findings from google scholar, the PCG-book and the Casual Creator’s paper [11] [2] [38]. By looking further into the similar interactive evolution systems (Picbreeder, Spore, Petalz) we found that all of them, to some degree, could be connected to the design patterns mentioned in Table 1. Picbreeder makes use of the no blank canvas where a user is always presented with randomly generated pictures to start evolving from. Petalz puts weight on the saving and sharing aspect where the user can share and even sell their creations in a virtual marketplace. Picbreeder and Petalz both use interactive evolution as a way to shape the users creativity as a none-goal-oriented process. Spore however uses it for “beauty” but also how the choices made by the user affects the game.

Petalz and Spore are simulation games that use an indirect control scheme. We wanted to know more about this genre after reading about what made these games addictive.

The artifact we are going to create started to steer towards the design patterns in the Casual Creators paper by using the genetic algorithm approach and UI-design from Picbreeder, the sharing feature in Petalz, the game-aspect of Spore and the open-ended structure of simulation based games e.g. Galactic Arms Race. But instead of hiding the interactive evolution like GAR, we will instead expose it to be directly controlled by the user.

In the beginning we wanted to create a game with interactive evolution, but after reading about Casual Creators it became apparent that it would be hard to follow the design patterns mentioned. The sharing and mutant shopping aspects are hard to integrate without ruining the “problem solving-experience” of a game. If the artifact would become more like a puzzle, it would ruin the creativity aspect of interactive evolution, because there would only be a limited amount of solutions. Twijnstra talks about the differences between puzzles, games and toys. He defines them by saying that he does not draw a strict line between them but mentions how the user interacts differently with them [40].
In Figure 1 we see that in puzzles, the user is seen as an actor, following instructions in order to succeed, whereas toys are on the other end of the scale. Here the user is an author, creating their own experience without any guidelines. He defines games as puzzle-toys and places games in the middle. However, as Marc Prensky mentions in his book, toys, games and stories can also be simulations [30]. Therefore our artifact fits better as a “simulation game” with an open-ended structure, meaning that if you want, you can make a game out of it but if you just want to be creative, there is room for that as well.

All of this led us to think of a new way of using interactive evolution in games. Where you create a new artifact based on the important parts of each project (Petalz, Picbreeder, Spore and GAR) and also follow the design patterns proposed by Compton and Mateas [11].

4.1.3 Creating a new design solution

After thoroughly looking through the gathered information we concluded that there is no artifact that uses interactive evolution as a main mechanic in a game. We have seen how fun interactive evolution is in tools that are non-goal oriented. What these tools share is the aspect of an indirect control scheme. There are also games that have an indirect control scheme, and the genre where they often use it is in simulation-based games. We believe the thoughts in Table 1 can be directly applicable for what makes the interactive tools e.g. Picbreeder and Petalz fun and addictive. By creating an artifact that is a simulation-based type of game mixed with how you use the creative tools, we can learn what users think about it in a game setting.

Working with the design science approach, we will find our solution through an explorative research process. Therefore we create an artifact following the Casual Creators design patterns. But instead of only being a tool for being creative, we want our artifact to take on a more simulation game-like approach. We will take the problem solving parts from Spore. An example of this is in the cell-stage in Spore, where the player can choose different mouths that change the behavior of the gameplay. The
artifact’s appearance and user interface will look similar to Petalz and Picbreeder’s user and breeding interaction.

4.1.4 Implementation of the artifact
Now that we have created our own design solution we can start creating the actual artifact. In design science it is important to be able to validate the relevance of the design solution. If we discover any flaws we will modify our solution accordingly to embrace the iterative approach of design science.

4.1.5 Validation of the artifact
To begin with, we will perform semi-structured interviews regarding the problem area. This method has the advantage of an open ended interview but with a more focused survey [13]. While users are testing we will also document their expressions and feelings. The documentation from these interviews will be used to develop a questionnaire which will be our main source of data gathering.

To validate the artifact we will perform tests with external users. We will create a questionnaire that can be filled in after a user has tested the artifact. Some of the questions will be answered Yes or No. However, those questions will be followed by an open question to let the user explain the thoughts behind their answer. The open questions are non-obligatory because we want to gather as much data as possible. As this study is explorative, the answers from the open questions are important to get a better understanding of the problem area.

4.2 Method discussion
Design science [12] focuses on the creation of an artifact. There are currently no artifacts that we can properly try on, because the shutdown of Petalz. Picbreeder is still running but it is only a creative tool with no game-aspects. Spore is also available but it has too many game-aspects and is hard to test the Casual Creators design patterns with. This means that we have to create our own artifact to test on; therefore a case study approach would be difficult. By making our own artifact we think it will have a positive outcome. In terms of us being able to design it by following the Casual Creators’ methodology but also focus on the simulation based game aspects. After considering, we did not choose to perform a field study on Galactic Arms Race. GAR is not a simulation based game and we think that interactive evolution fits better in that genre because it has more similarities. In GAR, the evolutionary part is hidden from the player and with a global population that is shared for between all the users. We think that it will work better to ignore the global population part, and instead take on a passive play-style, similar to what Picbreeder and Petalz have used.

As we are testing the design-aspect of our artifact, we cannot conclude anything from the data that our program generates. Design and feelings are hard for a computer to make sense of, which means that we will need actual people to test our artifact on in order to get valid data [2].

To validate our artifact we did not use a Likert-scale rating system. As Likert-scale is a scale in which the user is specifying their level of agreement or disagreement of a statement, they will not generate any concrete data for us. Yannakakis et al. mentions that ratings are not numbers; with this they mean that you cannot translate an adjective to a number. Scale ratings are also non-linear because each user has their own assumption of the answer they provide [41]. We want to have at least some concrete data to go on, as we already have open questions.
4.2.1 Alternative methods
An alternative to our chosen method could be to instead of having a quantitative approach we could have worked with focus groups. A focus group can sample data from people within a problem area in a more natural way than an interview could [42]. This would however require us to find different kinds of people that would fit our tests. The data we would gather would also become difficult to analyze.

As we are using an explorative method to research our problem, unstructured interviews is a popular choice to gather data. This would have been a good approach as it would lead to more qualitative data. However, with time being scarce, we will choose to perform semi-structured interviews that can form a questionnaire instead. We will try to make it as open as possible so we can get data similar to what unstructured interviews [37] would generate.

5. Results
This section will first explain how the artifact was created as the solution and its different aspects. After the solution is presented, the data gathered from the interviews follow by the questionnaires are summarized.

5.1 Solution
The artifact created as a solution is called Genetic Olympics. When played, nine randomly generated “Olympians” will automatically start running from left to right. This follows the Casual Creators methodology, where the user should not start designing from a blank canvas seen in Table 1. Another design pattern in the Casual Creators methodology is the “Entertaining Evaluations”. To connect this to our artifact we let our Olympians be able to express feelings depending on how they perform. Examples of these expressions are: sweating, cheering, hanging their head in shame and exploding.

We created four different activities for the user to play with: jumping, running, slow run and power. An explanation of each activity is provided in Table 3.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
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<tbody>
<tr>
<td>Jumping</td>
<td>In this activity the Olympians tries to jump over an obstacle. The user has control over the height of the obstacle. This provides variation, but limits the user to only be able to increase or decrease the height. This limits actions to encourage exploration for the user, associated with the design pattern seen in Table 1.</td>
</tr>
<tr>
<td>Running</td>
<td>In this activity the Olympians are to run as far as possible. The user can control the length of a lap.</td>
</tr>
<tr>
<td>Slow run</td>
<td>In this activity there is a wall filled with spikes. If an Olympian runs into the spike wall, they will explode. It is up to the user to decide what to do here, but breeding a short and wide Olympian will result in an Olympian only running a short distance and possibly survive. The user controls the spike wall’s location.</td>
</tr>
<tr>
<td>Power</td>
<td>In this activity there is a power meter placed in the field. The power meter measures the force that an Olympian has when they collide with it. The force is calculated with the current speed and the weight of the Olympian. The user can control where to place the power meter.</td>
</tr>
</tbody>
</table>

By creating a series of different activities the users have many paths to choose. This is one of the fun and addicting features of a simulation based game, according to Maximum Games [9].
thought behind the chosen activities came from competition between AI-agents. We wanted
something that was fast and instantly recognizable. Therefore, the Olympic Games was chosen
because it has many different activities that requires different skills. Each activity only takes a few
seconds to complete. This enables the feedback to become apparent to the user. By also having
Olympians that have human-like appearance, makes it easier to spot the subtle differences. The first
activity that we created was the jumping activity. This activity had a wide variety of actions that could
be performed. Since the obstacles could be raised or lowered by the user, it had a lot of interaction that
gave the feeling of control. To make use of the wide variety of different looking Olympians, the three
other activities were made so all types of Olympians could perform well in at least one activity. The
different activities can be seen in Figure 2, and the selected activity can be altered with the plus and
minus buttons.

![Figure 2: The different activities in Genetic Olympics](image)

5.1.1 Breeding
The user is presented with the Olympians placed in a row, sorted by weight. In Table 1 Compton et al.
talks about the uses of a “chorus line“. We used the chorus line concept in our own way; instead of
showing the generated Olympians we show the user all the possible choices, making it easier to
choose what you find appealing.
The user can select any number of Olympians to breed. The breeding controls various amount of variables connected to a body part, e.g. length of legs, size of head, width and height of the body and colors. Having the freedom to choose any number of Olympians and the different outcome from the selected Olympians also connects to the multiple routes aspect seen in Table 2. To control the mutation of the breeding, the user can affect the grade of mutation with two different settings, low or high. When low is chosen, the offset value ranges from -3 to 3. When high mutation is chosen, the offset ranges from -10 to 10. This value is then added or subtracted to each gene after crossover is applied. When the user is done choosing a new population of nine Olympians is created. An effect of the entire breeding process is that the users will (if they have a goal) repeat the breeding process as many times as they want, hopefully until their goal is reached. This effect can be connected to what Maximum Games mentions about simulation based games addictiveness and fun factors. The repetition grants the user the satisfaction of reaping what they sowed. The open-ended structure also gives the users freedom to set their own goals.

5.1.2 Choice of crossover methods
An Olympian is created with body parts of various sizes. When applying a crossover method on a population, we needed some genes to mix. The genes had to be easily visible for the user, because of the importance of instant feedback seen in Table 1. Instead of only seeing a value changing behavior of an Olympian, we wanted it to affect the Olympians appearance as well. We decided that the key body parts would suffice as these types of genes. Genes of a parent as a string: [body width, body height, head radius, color, leg length]. A further explanation on each gene is provided in Table 4.

<table>
<thead>
<tr>
<th>Gene</th>
<th>Description</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body width</td>
<td>The width of an Olympian’s body.</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Body height</td>
<td>The height of an Olympian’s body.</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Head radius</td>
<td>The radius of an Olympian’s head.</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 4 information about an Olympian’s genes
The color’s min and max values are working a bit differently. In our program there is a palette that contains 16 different colors. The color is represented by a number between 0-15. If the color would have a number higher than 15 it would loop around so as an example, the color with value 16 will result in color 0.

The color applies to different parts such as the head, body, arms and feet. The Olympian’s body color is decided first. The other parts are set by an offset from the body’s color.

<table>
<thead>
<tr>
<th>Color</th>
<th>The length of an Olympian’s leg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The artifact we created allows different amounts of parents to breed with. To solve this we implemented different solutions depending on how many parents were selected to breed. All genes except color has a min and max-value to avoid bugs of negative values or values that are not comprehensible by our equations. When two parents are selected for breeding the arithmetic crossover is used. The arithmetic method is a crossover operator that linearly merges two parents’ genes to produce two new offspring each following a unique equation.</td>
</tr>
<tr>
<td></td>
<td>[ O1 = a \cdot Parent1 + (1-a) \cdot Parent2 ]</td>
</tr>
<tr>
<td></td>
<td>[ O2 = (1-a) \cdot Parent1 + a \cdot Parent2 ]</td>
</tr>
<tr>
<td></td>
<td>Where ( a ) is a randomly chosen weight value between 0 and 1 that is set before each new offspring [15] [17] [43]. We chose the arithmetic crossover method because we think it makes more sense for the user, since it only allows for offspring to fall within the two parents genes.</td>
</tr>
<tr>
<td></td>
<td>The uniform method is used when three or more parents are selected. The uniform crossover provides the uniformity in combining bits from both parents. Randomly generate a number between for example, 0-1. If the number is zero, the gene will have the same value as the first parent, if one; the value is the same as the second parent. Each gene in the offspring undergoes this process [17] [15]. This method was chosen because it also works on more than two parents.</td>
</tr>
<tr>
<td></td>
<td>When only one parent is selected the offspring is only affected by mutation of the selected Olympian. There is no crossover operator that would make sense here, because of them focusing on mixing two parents to form offspring. It is important to mention that mutation also applied after the crossover methods. This is because we wanted to generate some kind of variation on the appearance but also to avoid never Olympians never being able to perform better.</td>
</tr>
<tr>
<td></td>
<td>5.1.3 Fake physics</td>
</tr>
<tr>
<td></td>
<td>Physics in the program is simple. It is not trying to mimic that of the real world, but instead look appealing for the entertaining evaluations pattern seen in Table 1. The physics are also there to make it easier for the user what to expect from an Olympian. As an example of this, the thin and long legged Olympians will jump higher than the short stubbed, bulky ones. The different body parts of an Olympian define how well they will perform. The Olympians has different traits. The weight served as a main variable because the other traits are based on it, but were tested to look entertaining</td>
</tr>
</tbody>
</table>
according to the appearance of the Olympian. In Table 5, the variables names are shortened down for convenience and readability. These variables are:

- \( W \) = weight of the Olympian
- \( w \) = width of Olympians body
- \( h \) = height of Olympians body
- \( L_1 \) = Olympians leg length
- \( h_r \) = Olympians head radius
- \( V \) = fall speed
- \( S \) = stamina
- \( F_{\text{jump}} \) = jump force
- \( L_{\text{speed}} \) = leg speed
- \( O_{\text{speed}} \) = Olympian speed

All of these variables are necessary for simulating the Olympians. A further explanation can be read in Table 5.

Table 5: Formulas used for “physics” in Genetic Olympics

<table>
<thead>
<tr>
<th>Trait</th>
<th>Description</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>The weight ( W ) is the total weight of the Olympian. By summing all body parts we get something that replicates a mass.</td>
<td>( W = \frac{(w \times h) + \left((hr^2) \times \pi\right) + \frac{L_1}{2}}{10} )</td>
</tr>
<tr>
<td>Fall speed</td>
<td>The fall speed ( V ) of the Olympian is dependent of its weight for the reason of entertaining evaluations. It does have a minimum value of 0.2, if the speed falls below 0.2 it is automatically set back to 0.2.</td>
<td>( V = \frac{W}{70} )</td>
</tr>
<tr>
<td>Stamina</td>
<td>The stamina ( S ) decides how far an Olympian can run before becoming tired and de-accelerate.</td>
<td>( S = \left(\frac{h + \frac{L_1}{2}}{100}\right) + \frac{4}{(w \times 5)} )</td>
</tr>
<tr>
<td>Jump force</td>
<td>The jump force ( F_{\text{jump}} ) decides how high altitude based on weight an Olympian can jump. In Figure 4 you can see the jumping being performed.</td>
<td>( F_{\text{jump}} = \frac{12}{w} + (L_1 \times 0.5) )</td>
</tr>
<tr>
<td>Acceleration</td>
<td>The acceleration ( a ) depends on the weight and leg length of an Olympian.</td>
<td>( a = \left(\frac{0.002}{W}\right) + \left(\frac{0.002}{L_1}\right) )</td>
</tr>
<tr>
<td>Leg speed</td>
<td>The leg speed ( L_{\text{speed}} ) is how fast an Olympian’s legs will move in a pendulum-like motion (mimicking running).</td>
<td>( L_{\text{speed}} = (O_{\text{speed}} \times 10) )</td>
</tr>
</tbody>
</table>
5.1.4 Saving and sharing
The user can save an Olympian’s stats to a string that can be shared with other users or yourself to use at a different time. The saving and sharing aspect of Genetic Olympics was implemented to connect another design pattern proposed by the Casual Creators methodology. By saving and sharing, the users can find inspiration from other users but also feel pride of their creations.

5.1.5 Choice of platform
We used the fantasy console PICO-8, to create our test environment. PICO-8 uses Lua as the built-in language. Lua is a scripting language. However the creator of PICO-8 has made a few tweaks to facilitate development. The program also has tools integrated; the tools can create sprites, maps, sounds and music to speed up the development process [44] [45]. The questionnaire was made with google forms and the data was formulated in excel. We chose to work in PICO-8 because we are confident in writing code in Lua and how easy it is to get started without having to set up an entire framework before you can start.

5.2 Data summary from interviews
We held a testing session followed by interviews on the 12th of April, 2017 at Malmö University. The test revolved around the entirety of the program, allowing the user to try all the different mechanics and activities. We did not give the users any instructions; we simply let them use their own imagination. If the users had any questions we would answer them. There were in total four interviews, all of which were with students at Malmö University.

As this was a semi structured interview the questions were not always asked as stated in Table 6. These questions were asked differently depending on the circumstances, but the answers are connected to the points below. For a summary of the data gathered from our interviews, see Table 6.
<table>
<thead>
<tr>
<th>Question/Statement</th>
<th>Summary of answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comments on the user interface</td>
<td>It was easy to understand after playing around with it a bit.</td>
</tr>
</tbody>
</table>
| Did you have or make any goals during your test? | All testers indirectly made some kind of goal, always related to “completing” one of the four activities.  
All testers tried to solve the hardest problems, e.g. jump over the maximum number of obstacles or shortest distance run by the fat Olympians in slow run. |
| What did you enjoy the most?             | How well the algorithm for breeding was working.  
The two activities, slow run and jumping were fun because of them contradicting each other, that way if you tried to solve jumping and then going over to slow run, you had to breed the Olympians to become fat and slow instead of skinny and fast.  
Buggy legs look funny. Looked like the Olympians were moonwalking.  
Funny feedback, sweating/crying and randomized body parts. |
| What activity did you enjoy the most and why? | Slow run and Jumping were better than Running and Power because there was something to actually solve rather than pressing play and see numbers changing. |
| In what way did you feel creative while using the program? | The ability to create a better “AI” was creative.  
The ability to choose which Olympians should be kept and not when trying to solve a problem was nice. |
| Was there anything you didn’t like?      | Too little control in some places  
A better explanation to what “high/low-mutation” means and does.  
Some things felt misleading while inside the breeding menu  
All activities did not have the same amount of “fun”. |
| Describe if there was an addictive aspect at any time while testing | For a short period there was, usually until a problem was “solved” or a goal was met.  
It was fun to not have full control; the “surprise” moment occurs happens after you start with a new selection of Olympians. |
| Documentation of other worthy notes      | Fun: Laughing from the testers occurred when the Olympians started to cry/sweat or cheered. Some were really funny looking and that also made testers chuckle.  
Reactions: Some testers mimicked the Olympians reactions when they cleared a jump. |
5.2.1 Data from questionnaire
When the questionnaire was finalized, it was published along with the artifact on both itch.io [46] and Lexaloffle [45] forums. The open-ended questions were optional but the questions connected to the tables below were obligatory. There were a total of 34 users who provided answers. The answers in this document are summarized. All of the answers can be read in the appendix.

![Approximate time played](image)

*Figure 5: Time played*

![Most entertaining activity](image)

*Figure 6: Users thoughts on the most entertaining activity*

**Question 1. Why did you enjoy this activity more than the others?**

- For the jumping activity, the users stated that it was easy to see progression. There was a clear goal to overcome and the goal (obstacle height) could be controlled.
- For the running activity, a user stated that the longer rounds which required both speed and stamina were entertaining.
- The slow run activity was the most unconventional according to a user, and another user thought it was fun to see the bulky Olympians being good at something.
- In the power activity, the users liked how a combination of speed and mass was applied, but also how the feedback was presented on the performance of the Olympians.

The core part of Genetic Olympics

- Breeding aspect
- Share your creations
- Entertaining evaluations
- Aesthetics

100%

Figure 7: Users thoughts on the core part of Genetic Olympics

Question 2. Tell us about a moment you really enjoyed:

Many users answered that seeing all of their Olympians jumping over the obstacles were the most enjoyable moment. It was also entertaining to see that the breeding had an impact on appearance and performance, but also the fact that you had to think a little.

Did you feel like you had control over the outcome?

- Yes 56%
- No 44%

Figure 8: Users thoughts on control over the outcome
Question 3. Follow-up to the table above: How and why?

Users answering yes:

Users thought that by seeing similarities after breeding you were able to choose which Olympians you wanted to continue breeding. Many pointed out that there was never a moment of full control, but rather partial control with the help of high and low mutation setting. Depending on how many Olympians you chose to breed, it would give a different outcome. One user pointed out that having the ability to control the obstacles in the different activities, also gave the feeling of control.

Users answering no:

Many users felt that the outcome was completely randomized and that it was difficult to make out what your choices led to in the matter of better or worse. Some also thought that they could steer the general direction of the Olympians but micromanagement was non-existent.

![Figure 9: Users thoughts on the saving and sharing feature](image)

Is saving and sharing important in a program like this?

No 44%

Yes 56%

Question 4. If you set up any goals during playtime, tell us about them

There were a lot of different goals that the users mentioned; some were similar to each other.

Goals set by the users:

- Make the entire population of Olympians jump over the obstacles.
- Breeding Olympians to perform well in all activities.
- Creating the best or worst Olympian.
- Getting the Olympians to jump as high as possible.
- Seeing the different appearances you could get from breeding.
Figure 10: Users thoughts on if Genetic Olympics would be more enjoyable as a game

Figure 11: Users opinion on more usage of the breeding mechanic in games

**Question 5. Is there anything else you would like to add?**

To sum up the answers, most of them were ideas on how to continue expanding the artifact more into a game. One user mentioned how the program was transient. He thought it could be fixed by augmenting the saving feature. The lack of not being able to save multiple Olympians could lead to losing all the progress you had made. By changing the saving feature, some sort of progression could be added. As an example, clearing multiple activities with your saved Olympians, letting you choose which Olympian to perform in what activity. Some users pointed out that having minor goals set up from the start would lead to users playing longer. One user pointed out that all activities should have the same structure. In the jumping activity there is a clear goal to what you can accomplish, in the running activity all the Olympians always survive. To make the running activity more interactive, a
user mentioned that by adding a “monster” that chases the Olympians, would make the running activity more fun. Other answers from the users that would enhance the artifact were:

- Names for the Olympians to easier recognize the ones you want to breed for later.
- More physics e.g. ragdoll, breakable objects.
- Higher resolution
- Order the Olympians in the breeding menu in more ways than weight.

There were also users who were satisfied that stated, the concept was fun and a good way to learn how interactive evolution and genetic algorithms work. One user said that it was perfect for what it is. You make your own experience without any implication that you are playing improperly. The breeding feature is interesting and could be fun in other types of games but it has to make sense. As an example, a Tamagotchi-like [47] game would be perfect but a shooter would not.

6. Analysis and discussion

This section will bring up each of the questions asked in in the questionnaire, to be analyzed and discussed. Note that the order of these questions might not follow the same order as they are stated in the results. The coherence between these answers was used for the order.

In Figure 6 we can conclude that running, power, and slow run were not popular activities. The jumping activity however was very popular where 70% of the users thought it was the most entertaining. By looking at the answers from the Question 1 we could see that most of the users felt that jumping had a clear goal, was easy to see progression, and was also entertaining to see the Olympians jump. We think that the jumping activity was more popular because it had a goal set by default. In all the activities except jumping, the Olympians were just running. Instead of trying to get a bigger number like in the running and power activities, it seems to be more entertaining to breed and evolve your Olympians towards a goal. When comparing jumping to the other three activities, looking at the Casual Creator’s methodology, instant feedback, and entertaining evaluations are much easier to recognize. We consider it easier to spot the optimal Olympian and continuously breed it towards being able to jump over the obstacles than it is to breed an Olympian with good stamina in the running activity. It is worth noting that when the users start the program, the first activity is always jumping. Therefore a question that could have been appropriate to have beyond asking how long they used the program would be to ask how many activities they played. Most of the users seemed to only have tried the jumping activity.

When looking at the answers of Question 2, we can clearly see that most of them are connected to reaching a goal. The most common answer was as an example, when all the Olympians managed to jump over the obstacles. An answer that was also common was seeing how your breeding had impact on both performance and appearance. The problem solving aspect seems to overtake the freedom and autotelic activity that the casual creator’s suggests. We wanted our artifact to be more like toy than a game, by having it land on the right side of the scale in Figure 1. We thought that the answers would contain more about the creative aspects of the artifact e.g. breeding funny looking Olympians or other none-goal oriented activities. This seems to be the case that Tom Francis mentioned; “The extent to which a game reacts to your choices with interesting results”. However if this would have been done as an interview, we could have asked a follow-up question on why they enjoyed that moment so much and discuss other moments as well.
When looking at Figure 8, we conclude that there is no clear indication on the users’ thoughts if they feel in control or not. The answers were similar on both sides, e.g. One user who answered yes, mentioned that they never felt fully in control but with the help of the different settings they could somewhat control the outcome. On the other hand, a user who answered no, thought that he/she could control the general direction of the outcome but micromanagement was impossible. We think that when it comes to using a genetic algorithm, a user will never have 100% controllability. We consider this to be a big flaw about using interactive evolution as a game mechanic. The risk of a bad/worse outcome will always exist to some degree. There was a user who mentioned something that could prevent this. By having the ability to store multiple Olympians that were favorable and load them whenever you want to use them be it for a specific activity or other reasons, would lead to a reduction of the player not feeling in control. It would also reduce the frustration caused by overwriting your progress if you were to breed “wrongly” e.g. unwanted outcome after breeding. Another way to reduce confusion and frustration could have been done by enhancing the UI of the artifact rather than altering how the interactive evolution works. As an example of this, a user mentioned how he/she was only breeding Olympians who jumped over the obstacles and the next generation resulted in no Olympian managing to jump over. We think that, by giving the users better instructions on what the different settings did; could have made the users feel more in control. If we would have been clearer on what outcome depending on how many Olympians were chosen for breeding. We expected to get more answers like these, because of how we designed our artifact towards the Casual Creators’ methodology. Casual Creators proposes an explorative nature in creation, without any goals. The weakness here is how we designed the artifact to be a simulation based game but still feel like Picbreeder and Petalz. In Figure 9 the answers almost had an equal amount of yes and no. We think that the reason for this is the inability to create a fully unique Olympian, e.g. the values in the gene string does not have the same amount of impact that Picbreeder or Petalz has. If we were to add genes to only control the appearance of the Olympian, similar to the color gene, the saving and sharing feature would make more sense. There are two directions to go from here. Either we could have made the artifact more towards what a game resembles by adding features mentioned in Question 5 of the questionnaire results, or going towards the other end of the scale in Figure 1 and make a toy. If we wanted to make the artifact more like a toy we could have as an example, altered the jumping activity to start without any obstacles. We think the users would not instantly set a goal to jump over it but instead play around with the different breeding settings. To further enhance the artifact we could also have generated the first generation of Olympians to be around average size.
This would increase the longevity and explorative nature of the artifact. Furthermore, it would also let the user choose whatever direction they want rather than seeing all different types of Olympians directly.

When looking at Figure 10 we clearly see that the majority of the testers answered yes. If we knew about this data before our research began, our artifact would be created as a game instead of having the properties of both games and toys. Many programs that use interactive evolution are tools for development or creativity e.g. Pichreeder and Ropossum. In Galactic Arms Race interactive evolution is used but the player is not actively controlling it. We thought that instead of taking the entire step of going straight to a game, we wanted to land in between games and tools. But when looking at Figure 11 we can conclude that users want to see more of the breeding aspect as a mechanic in games. The users seemed to enjoy how the breeding worked and we got answers about how it could fit as a Tamagotchi-like game. Another user proposed how it could be used for educational purposes to learn about the genetic algorithm procedure.

Answers from Question 5 gave us a lot of interesting thoughts, many of which were how we could improve the current artifacts functionality.

7. Conclusion

When creating a game with interactive evolution, the design patterns proposed in the casual creators will help with the development. However, it seems that people want it to be goal oriented because of the enjoyment from reaching goals whether they are set by themselves or by the creator. This leads to a point where you have to choose to either make a tool or a game. From our tests it seems that making a game out of our artifact is the more popular choice. If that is the case, one should only take into account the design patterns proposed but not the idea of making a game without goals.

Interactive evolution seems to fit in simulation games. The freedom that interactive evolution and simulation based games provide is an important factor to take into account. This gives the user control and the ability to set up their own goals. Every choice made by the user must be clear to avoid confusion. As seen from the data of the questionnaire, there are many users who were confused about what their breeding resulted in. A lot of confusion that may occur is not necessarily related to interactive evolution itself but rather how the artifact is designed. In conclusion we think that every choice made by a user must be visualized and explained properly. When a choice is made, the user must know why their choice did or did not work, especially in a game. This is even more important in a game that uses interactive evolution because the loss of control that comes with it.

All in all, if we were to add additional features to our already existing artifact e.g. saving multiple Olympians, naming your Olympians, and player progression we think that there is a place for interactive evolution to be used as a mechanic in games.

7.1 Further research

By altering the artifact towards what a game resembles by adding what we discussed e.g. saving multiple Olympians, naming your Olympians, and adding goals to make all activities have the same level of interactivity. A case study could be performed on Genetic Olympics with better optimized questions to further explore interactive evolution in games. In the case study we would propose to look when interactive evolution stops being fun, in terms of how well you can balance the interactive
part. The research question could be formed similar to “How does interactive evolution work as a game mechanic?”

Another question that could be worth looking into is how a player’s patterns change if the artifact were to be gamified. Depending on how you gamify it, different results may present themselves. Examples could be to add goals and see how users react. Many users wanted goals to be added. This may not result in a positive outcome and the user might feel too limited with their actions instead.

From the answers in Figure 11 we see that the breeding mechanic is something the users want to see more of. We therefore propose to try implementing interactive evolution into an already existing game and see how it works alongside other types of genres in systems that already work. An example of a game could be Tamagotchi where you take care of a tiny creature. This could allow for breeding between creatures with different users, to create more unique Tamagotchi creatures.

As a final detail to add we have acknowledged some new information regarding a game that uses Interactive Evolution in a way similar to Genetic Olympics. The NERO video game [48] is a game that uses real-time neuroevolution to evolve AI-agents. The AI-agents behavior is evolved by a real-time Neuroevolution of Augmenting Topologies (rtNEAT), similar to what Galactic Arms Race uses. The gameplay becomes adaptive to what the player prefers. In the paper about NERO the authors suggests that a new genre of video games have been created in which the player acts as a coach that trains AI-agents. We have shown that it can be done without the use of a neural network but instead use a physics model. And by tuning a set of parameters by means of an evolutionary algorithm can work in a similar fashion. We therefore propose to further explore the possibility space of the game genre created in the paper by O. Stanley et al. in which the player coaches AI-agents to perform different tasks. By looking into the research performed in the NERO video game and Genetic Olympics, we believe there is a space that allows for a new artifact to be created, based on their teachings.

Bibliography


