Towards Interactive Evolutionary Camouflage Design

Rasmus Ploug
Game Dev. & Learning Technologies
University of Southern Denmark
Odense, Denmark
raplo20@student.sdu.dk

Emil Rimer
Game Dev. & Learning Technologies
University of Southern Denmark
Odense, Denmark
emrim19@student.sdu.dk

Anthon Kristian Skov Petersen
Game Dev. & Learning Technologies
University of Southern Denmark
Odense, Denmark
antpe20@student.sdu.dk

Marco Scirea
SDU Metaverse Lab
University of Southern Denmark
Odense, Denmark
msc@mmmi.sdu.dk

Joseph Alexander Brown
Computing Science
Thompson Rivers University
Kamloops, British Columbia, Canada
josbrown@tru.ca

***Abstract*—This project presents an evolutionary algorithm for texture generation that allows users to choose and manipulate camouflage patterns. The initial results of a pilot study provide some insight into usability and the users' ability to replicate a target pattern. The result is an evaluation of gathered data showing user tendencies and how they engage with the system. These tendencies include significantly different completion times for target patterns varying in complexity.**

Additionally, participants mostly agreed that the tool is helpful for future games and objects other than camouflage skins. The findings suggest potential applications for artificial intelligence in enhancing user customization and design flexibility. Further research must address technical limitations and explore broader game industry implications.

I. INTRODUCTION

The utilization of artificial intelligence (AI) has become a common practice in video game design for its ability to create different dynamic gameplay elements. One such element is the customization of the player's in-game character appearance, which often only has a predetermined number of options from which the player can choose. This paper presents an interactive evolutionary algorithm that allows the user to explore the space of possible camouflages.

Camouflage in games provides several aesthetic and mechanical values for the player. For the aesthetic elements, there are two rationales for camouflage. Games designers who worked on *Titanfall 2* (Respawn Entertainment, 2016) highlight the variation of camouflage as being the personal choices of mercenary units, fitting into the narrative of the game while allowing for customization of the player character.Mechanically, the game world may attribute a form of concealment from NPC characters or other players.

Aside from the aesthetic and mechanical features, there is also the question of monetization. Many games have used player skins for characters as a feature for payments from players. The ability to define a personalized look for player characters would be a desirable feature for purchase, either as a part of the base game or for an additional cost.

The presented system utilizes an evolutionary algorithm to dynamically create unique camouflage patterns. The algorithm employs different evolutionary principles to refine each generation of camouflage designs. It further enables players to customize their camouflage through user preferences and choices, increasing their agency. The paper also underlines the methods used to create the evolutionary algorithm. A pilot experiment, composed of a target-replication task and a questionnaire, has been conducted to measure the tool's effectiveness and usability.

II. BACKGROUND

Creating a tool to create icons, skins or camouflages has precedents within the game industry. An example of this was the ability to develop a personal emblem for the player card in *Call of Duty: Black Ops 1* (Treyarch, 2010). This emblem was seen by the opponent each time the player killed them. This incentivized the players to express themselves via this emblem as they could not reliably use the chat in the action-packed game. The emblem editor worked by having a limited amount of shapes that could be freely rotated and placed. Many sought to recreate a logo from their favourite series, team or brand. This concept has since been used by several other games, such as the *Battlefield* game series (EA DICE, 2002-2021).

Generating images and textures through evolutionary means has a rich history [1]–[3], but has seen limited application in commercial video games. Yoon *et al.* [4] presents one of the few evolutionary systems designed explicitly for producing textures for games.

Brown & Scirea wrote an article about evolving woodland camouflages for video games, focusing on the effectiveness of the camouflages in a forest setting [5]. Although both projects use an evolutionary algorithm to achieve the desired result, the goal for each project is not the same. Where Brown & Scirea's

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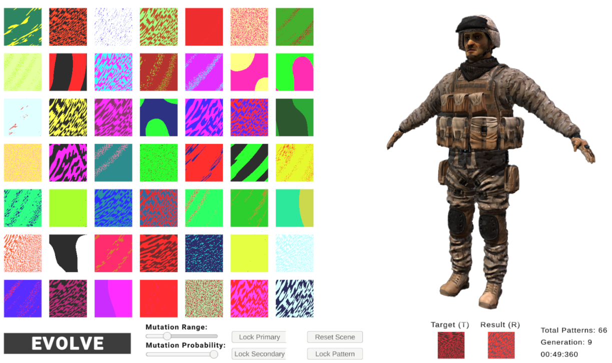

Total Patterns: 66
Generation: 9
00:49:360

Fig. 1. The user interface of the program. On the left, 49 squares, each with a unique camouflage pattern, are displayed. Below, the evolve button and the adjustable settings can be accessed. On the right, the model of choice can be placed. In this example, a soldier wearing a uniform is the chosen model for this project. Below the model is the interface for the target-replication task. Left-clicking the camouflages will select them, adding them to the user selection. Right-clicking the camouflage will preview the camouflage pattern on the model.

objective is to create effective camouflage in an arbitrary environment, this project focuses on empowering the user to create desired patterns easily. For this project, the effectiveness of the camouflage is unimportant as the focus is purely on aesthetics. These tools partly inspire this project, allowing players to create something on their own to express themselves within video games. However, the user is constrained only to create camouflage-like patterns through this system. The system, therefore, helps navigate a pattern space that does not allow for clear symbols to form.

III. METHODOLOGY

The following section aims to explain the implementation of the evolutionary algorithm.

A. *Textures*

The overall foundation of the evolutionary algorithm lies in creating and manipulating textures. A texture is, within the context of this project, a representation of intricate colors and patterns that constitute the appearance of a specific camouflage. These textures are gradient noises, that have been modified by various distortion nodes (none, twirl, spherize and radial shear) followed up by color nodes (foreground and background) which are all later modified and customized through the algorithm.

B. *Evolution*

The procedure of evolving these textures into new distinct camouflages involves a process of iteratively generating populations of candidate solutions based on user selections. These solutions undergo crossover and mutation operations to produce new, unique offspring over multiple generations. The program user selects a variety of camouflages of their liking from the population shown on screen; see Fig. 1. Each camouflage created for the next generation is, therefore, based on the variety and quantity of textures the user selects. This ensures that the next generation of camouflage coincides with the user's selections.

Furthermore, the algorithm memorizes all previous user selections to influence future offspring. However, the chance of camouflage of an earlier generation being used for the next evolution decreases with the age of the generation, i.e. a 1st generation of camouflage will be weighted lower than the 2nd generation. Therefore, the most recent user selections have priority over older selections.

C. *Crossover*

Each evolution of a new generation is facilitated by a crossover operation in which the exchange of genetic information between parent solutions is processed. Each user-selected camouflage is randomly picked and paired with another user-selected camouflage. These represent the parents of the offspring. Each pairing of parents undergoes an attribute selection process in which different features from each parent are mixed, resulting in a new, unique camouflage. Specifically, the algorithm chooses an attribute, such as color or pattern, from one of the parents (chosen randomly) and adjusts them slightly to avoid homogeneous offspring.

D. *Mutation*

Another feature is the random chance of mutations occurring during the crossover operation. Mutation serves as a mechanism for introducing new novel variations of camouflages into the population, thus increasing diversity and exploration while simultaneously preventing premature convergence. The mutation operation depends on the two variables M_{prob} and M_{range}. Respectively, these variables are responsible for the probability of a mutation occurring and the scale at which this mutation alters the attributes of the camouflage. The user freely adjusts these variables, which can be set to a decimal value within an interval of [0, 1], with 0 meaning no mutational impact and 1 meaning maximum mutational impact.

E. *Fitness Evaluation*

The fitness evaluation is a critical component in guiding the evolutionary process towards a suitable candidate for the next generation of camouflages. Unlike a traditional fitness evaluation based on objective criteria, this project's approach instead incorporates subjective measurements based on the camouflages provided by the user selections. This approach enables the algorithm to adapt based on personalized user preferences, resulting in generations of camouflage textures that align closely with the user's expectations.

F. *Color & Pattern Locking*

A feature in the fitness evaluation process is the ability of the user to exert direct influence over the evolutionary direction by preserving a specific color or pattern for a subsequent generation of camouflage textures. This feature of locking a particular color and/or pattern ensures that the specific camouflage attributes become immutable, guaranteeing the

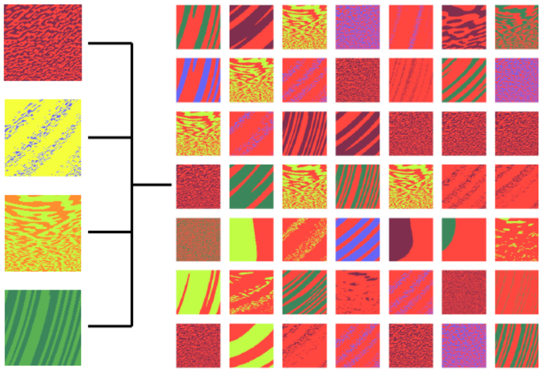

Fig. 2. This figure showcases the selection of four different camouflages. In this example, the primary color of the top selection has been locked, ensuring that the future generation only contains camouflages of the same red primary color. This also means that all secondary colors will consist of the secondary colors of the other selections, given no mutations occur. Settings: $M_{prob} = 0$, $M_{range} = 0$

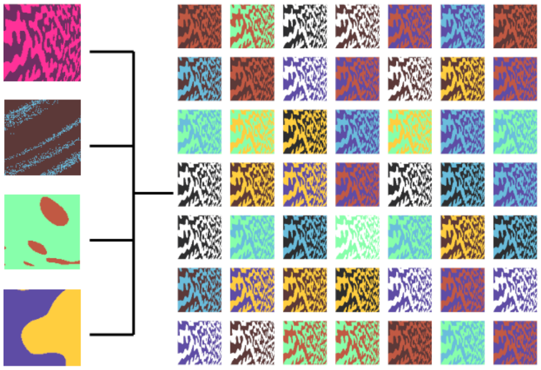

Fig. 3. This figure showcases the selection of four completely different camouflages, not sharing a single trait. In this selection, the pattern of the top selected camouflage is locked, ensuring that all of the camouflages of the next generation will include this pattern, given no mutations. Settings: $M_{prob} = 0$, $M_{range} = 0$

retention of said attributes for the next generation (unless a mutation occurs). Colour locking entails preserving a specific camouflage's primary and/or secondary color for the upcoming offspring. This is shown in Fig. 2, where the primary color is locked in, resulting in the following generation adhering to the specific color palette. Similarly, the pattern locking feature enables the user to safeguard a particular pattern configuration to preserve the following camouflage textures' structural integrity and visual coherence. Fig. 3 visualizes this pattern-locking feature. Finally, it should also be mentioned that these locking features can be combined, meaning that multiple attributes can be locked simultaneously.

IV. EXPERIMENT

This section will present the details of the a pilot study conducted to investigate the dynamic creation of personalised camouflages using this tool. The experiment was designed to test the program's usability and gain insight into the individual participants' ability to replicate a target pattern.

A. *Experiment Design*

The experiment is designed to have three parts, and was inspired by Bernhaupt [6, pp. 19-25]:

1) **Free-flow task**: an unguided task where the participants are encouraged to engage and learn by themselves. The period of the free-flow task is 5 minutes.
2) **Narrow-specific task**: Here, the participants are tasked with creating a replica of a random of three predetermined patterns varying in complexity, see Fig. 4. The context of this task was to imitate what players might have done in a real scenario, by copying another player's appearance. The target-replication task is conducted directly after the free-flow task to allow the participants to utilise newly learned skills and mechanics. The period for the target-replication task is user-determined as the participant will end this task when they feel the goal has been achieved.
3) **Questionnaire**: The overall purpose of a questionnaire within this experiment has been to gather quantitative insights. The questionnaire layout consists of a short introduction, a few introductory questions followed by usability questions and an open question on ideas for improvement.

V. RESULTS

A. *Data Analysis of the Target-Replication Task*

To investigate if the different patterns had any effect on the participants' replication task, three one-way ANOVAs were conducted to compare the mean Completion Time, Generation and Camouflages Chosen across the three targets: Target 1 (Simple), Target 2 (Moderate), and Target 3 (Complex). The independent variables in this analysis were the three targets that the participants were shown, varying in complexity. The dependent variables across the three tests were the Completion Time, measured in seconds, the Generation of the result and the total Camouflages Chosen throughout the task. The one-way ANOVA on Completion Time showed a significant difference among the different Targets ($F(2, 22) = 3.92$, $p < 0.05$). Using Tukey's HSD test, post-hoc comparisons indicated that the mean Completion Time value for Target 1 (Simple) ($M = 651.11$, $SD = 548.26$) was significantly higher than that for Target 3 (Complex) ($M = 216.67$, $SD = 117.60$), with a p-value of 0.037. The two other one-way ANOVAs did not significantly differ in Generation or Camouflages Chosen. The results from this analysis suggest that the complexity of the patterns significantly affects the participant's completion time of the replication task. Specifically, the study shows that the less complex the target pattern is, the longer it takes for the participant to complete the target replication. No findings indicate that the patterns had any significant effect on the generation of the result or the number of camouflages chosen throughout the task. Fig. 5 compares two target-replication tasks.

Fig. 4. The experiment involved three different target designs, ranging from simple to complex. These targets were randomly assigned to participants.

B. Survey Findings

The purpose of the survey was to assess the usability of the program itself followed by questions regarding the personal satisfaction of the participants and the evaluation of the tool itself. The survey encompassed 26 participants (22 males, 3 females and 1 person of another gender), with a mean age of 24.9 years ($SD = 6.72$). As introductory questions, the participants were asked about their experience with games and knowledge within texture and image crafting. 88% of the participants played video games at least several times a week and tended to be neutral ($M = 3.8$, $SD = 1.1$) regarding knowledge within texture and image crafting. Questioning the participants about the intuitiveness of the program, mixed responses were received. The majority agreed ($M = 4.8$, $SD = 1.1$), that the overall user interface of the program was intuitive, however, some parts of the program were more intuitive than others. Participants agreed that the color- ($M = 4.6$, $SD = 1.6$) and pattern locking ($M = 5$, $SD = 1.4$) mechanisms were slightly more intuitive than the mutation settings ($M = 4.1$, $SD = 1.7$), which had many mixed answers. The participants also answered questions about the target replication task. The majority agreed ($M = 4.9$, $SD = 1.5$) that the task was a success, agreeing upon a satisfying end result ($M = 4.7$, $SD = 1.4$). This is also shown by the majority agreeing ($M = 5.2$, $SD = 1.3$) that they would at least use one of their created camouflages in a real game. Participant were somewhat neutral ($M = 4.4$, $SD = 1.6$) regarding their perceived control over the evolution. Lastly, most participants agreed that this tool could be used both in future games ($M = 5.5$, $SD = 1.3$), but also as a tool to create patterns for objects other than camouflage skins ($M = 5.9$, $SD = 1.1$). Many participants also had comments for improvements on the tool. Being able to pick colors yourself was an occurring theme. Other comments suggested more clarity on the effects of the mutation settings. Lastly, the participants were conflicted with the design of the user interface, seeking a better user experience, especially with the locking mechanisms.

VI. CONCLUSIONS

This paper describes a system capable of dynamically creating personalized camouflage patterns. The final results demonstrate the potential of artificial intelligence in creating adaptable camouflage designs and other patterns for game objects. The system supports a sense of personalization and agency by actively enabling the user to participate in the selection process.

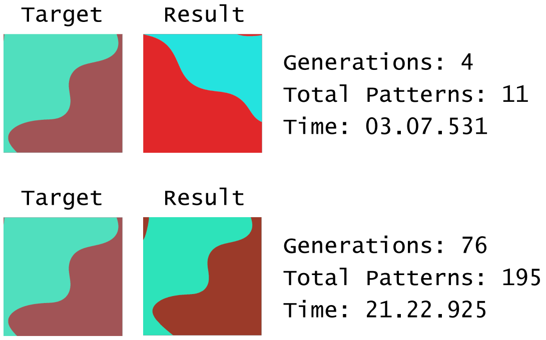

Fig. 5. This figure showcases two target-replication task results, both trying to replicate the simple pattern of Target 1. The top result, despite its faster completion time, shows a less accurate resemblance to the target, with fewer camouflages chosen and fewer generations of evolution. The bottom result closely resembles the target, with a slower completion time, more camouflages chosen, and more generations of evolution.

The experiment resulted in a significant difference in completion time between the simple and complex patterns during the target-replication task. Due to the simple pattern being less detailed, the participants were more inclined to replicate the pattern to perfection, thereby using more time on the task. In contrast, the increased details of the complex pattern resulted in the participants realizing that a perfect replication would be challenging. This led to a lower completion time and a less accurate replication result. The survey conducted during the experiment showcased an interest in the tool being implemented in the games industry. Overall, the participants expressed satisfaction with their created camouflages, which further emphasized the potential for future implementations of this tool. Additionally, the survey conveyed mixed results in regard to participant agency during the target-replication task.

To conclude, the tool successfully implemented an evolutionary algorithm for creating personalized camouflage patterns in a generic video game setting. The basis of this tool could potentially be expanded to multiple areas within the games industry and further research within this problem domain is suggested.

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