SBSE As Gaming

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Abstract. One way to understand meta-heuristic optimisation process is to look at it as an automated trial-and-error problem solving technique. This view provides interesting parallels to video gaming, which often requires the gamers to solve various problems using trial-and-error approaches. This paper considers the possibility of formulating optimisation problems in SBSE as video games and discusses challenges that are anticipated. The paper concludes with a demonstration of a proof-of-concept implementation that casts test data generation problem as a spatial puzzle.

1 Introduction

Trial-and-error is a fundamental problem solving skill that also allows the solver, be it a human or an algorithm, to acquire the domain knowledge during the process of problem solving. Meta-heuristic optimisation algorithms can be viewed as intensive and systematic trial-and-error problems solving techniques that are fully automated by the use of the representation of solutions and the fitness function. Algorithms iteratively try out various solutions using the fitness function, which provides feedback on whether each solution was a success or an error; algorithms then generate the set of next solutions to try out based on the feedback.

One area where people subscribe to voluntary problem solving tasks, which can sometimes be surprisingly challenging, is video gaming. For certain types of video games, gamers are expected to interact with the virtual environment, trying to achieve various kinds of goals given by the games: they try out various solutions, learn what was good or bad about their previous move and then try again until they succeed.

The parallel between the cores of these two activities raises an interesting question: can we present SBSE optimisation problems as video games? Assuming that the resulting games are playable and, furthermore, *enjoyable*, the benefits might be enormous. We will be able to rely on human brains for optimisation: not artificial, but real intelligence with flexibility and adaptability. The participation from gamers will be voluntary, enabling practitioners to crowd-source solutions to complex optimisation problems.

There are many challenges to be expected. The criteria for 'enjoyable' experience vary significantly between individuals and are hard to define. Moreover, it is not clear whether the reformulation of optimisation as gaming will be possible with all classes of optimisation problems or not. Gamers seek rewards in achieving pre-defined goals; optimisation seeks rewards in discovering the unknown, i.e. the solution. There lies the critical challenge in this very difference: creating a meaningful experience with a pre-defined goal out of a problem with unknown solution.

This paper aims to illustrate the challenges related to the reformulation of SBSE as gaming and presents a proof-of-concept spatial puzzle game that is in fact a test data generation technique. Section 2 investigates the art of game design. Section 3 discusses the theoretical aspect of the reformulation and discusses ensuing challenges. Section 4 presents a proof-of-concept implementation of a game called 'Turn Your Iguana': a spatial puzzle that generates numerical test input for programs. Section 5 concludes.

2 The Art of Game Design

Designing a good game, whether it is electronic or not, is in many ways closer to an artistic craft rather than a technical discipline. Although there are certain established 'genres' one can rely on, a truly unique gaming experience is often a product of imaginative thinking rather than compliance to strict rules. As a result, there is little literature on what constitutes gaming in general, not to mention video gaming, and how to formulate a gaming experience. Nonetheless, it is worth looking into some widely known concepts for inspiration.

2.1 Elements of 'Playing'

Callois classified the essential elements of the activity of "playing" as follows [1, 2]. While his was an anthropological observation of playing in general, much of these characteristics can be applied to video gaming in various degrees and combinations as video gaming is certainly a form of playing.
Agôn represents a group of competitive games, where equality of chances are artificially created and the competition is between the skills of the players. The sense of equality is essential, although it may not always be possible to provide the players with absolute equality. Examples would include chess and go.
Alea is the Latin name for the game of dice and, naturally, represents a group of games in which the decisions are independent of the players, who have no control over the outcomes. Examples would include roulettes or lotteries.
Mimicry is based on the acceptance of an imaginary world so that the players can submit oneself into an alternative world and become an illusory character. Examples would include children playing house or various role-playing.
Illinx represents a group of games that are based on the pursuit of vertigo; an attempt to destroy the stability of perception momentarily. This often involves physical sensation. Examples would include roller-coast rides or swinging.

2.2 Implications to Our Approach

The four elements described by Callois are all present in video gaming. It is easy to see that trade-offs between *agôn* and *alea* is a crucial element in any gaming.

Advances in computer graphics allow highly immersive experiences for the players, which would align with *mimicry*. Regarding *illinx*, the realistic experience of physical sensation in the virtual environment is often a measure of evaluating how good video games are (e.g. video game users will discuss the sense of speed or realistic representation of collisions). The recent usage of motion sensing technology in game controllers are closely related to both mimicry and illinx.

Controlled use of all four elements can help reformulating SBSE as an enjoyable gaming experience. A SBSE-game that aligns itself completely with agôn will be essentially asking human the answer for the optimisation, whereas one that aligns itself completely with alea will be essentially no better than random search. It is critical that we provide a good trade-off between these two elements that there exists room for human intelligence.

Mimicry is a concept that can provides a *theme* to an otherwise taxing activity. Within our SBSE-game, we need to present the optimisation problem in a meaningful and attractive context so that the player can be voluntarily motivated. Finally, the elements of illinx introduced by physical sensation through motion sensing technology can provide an intuitive control interface for complex optimisation problems.

3 Reformulating SBSE as Gaming

3.1 A New Genotype Space

Meta-heuristic optimisation algorithms operate in genotype spaces. A genotype space can be defined by $(\mathcal{R}, \Omega)$, where $\mathcal{R}$ is the set of all possible candidate solutions specified in the given representation format and Ω is a set of *move* functions $\omega : \mathcal{R}^m \rightarrow \mathcal{R}^n (m \geq 1, n \geq 1)$ that allow the algorithm to move from one location in the space (i.e. a candidate solution) to another. Examples of such a function ω could be either a mutation operator in Genetic Algorithms ($m = 1, n = 1$) or a neighbourhood function in local search algorithms ($m = 1, n =$ pre-defined neighbourhood size). A genotype space $(\mathcal{R}, \Omega)$ should satisfy the following conditions to be effective:

- **Expressibility:** any candidate solution in the real world (phenotype space) should be able to be expressed by the representation, i.e. should have a counterpart in $\mathcal{R}$.
- **Reachability:** for any given pair of $r_1 \in \mathcal{R}, r_2 \in \mathcal{R}$, it should be possible to modify r_1 to r_2 by applying a series of functions in Ω.

Reformulating an instance of SBSE problem as gaming is essentially to conceive a new instance of genotype space $(\mathcal{R}, \Omega)$ that can also be interpreted as a gaming environment. The set of all possible candidate solutions $\mathcal{R}$ equals the set of all possible game states, be it the current condition on the game board or the current location of the player in a virtual environment. The set of functions Ω equals the set of 'moves' allowed to the player. More importantly, this new instance of genotype space should also satisfy the above conditions.

The final ingredients to the reformulation is, naturally, the enjoyability of the whole experience as a game. This largely depends on the choice of $\mathcal{R}$ and Ω and how they relate to the classifications and genres described in Section 2.1. This is an unknown territory.

3.2 Challenges

Here we discuss some of the challenges that we anticipate while trying to reformulate SBSE as gaming.

The Unknown Goal Problem: The motivation for a gamer to continue playing a game is the sense of achievement. This can be a profound motivation, to such an extent that it has been proposed to use gaming as a medium for social movements [3]. Therefore, if the reformulation of SBSE were to be successful, it needs to present the gamer with a clearly defined and achievable goal and a feedback on how close the gamer is to achieving the goal.

It is important to distinguish the goal from the solution. For certain classes of SBSE problems, the goal is clearly known while the solution is not: let us consider fitness functions that are widely adopted for test data generation for structural coverage [4, 5]. Regardless of the statement or branch that we want to cover, the ultimate goal is to minimise the fitness value to 0, even though the solution (i.e. the input data) to the problem is not known. Only when the goal is known it becomes possible to provide feedback to the gamer, which is essentially the difference between the goal and the current state of the SBSE-game.

However, there are SBSE problems for which the achievement of the goal is untestable. For instance, one goal in search-based requirement analysis is to find a subset of software requirements that result in the maximum revenue and the minimum development cost [6]. Since the underlying NRP problem is NP-complete [7], it is not possible to know the maximum possible revenue for a given budget. There is a close parallel to the concept of 'non-testable' programs [8]. The goal is the solution: if we knew it, there wouldn't have been the need for optimisation. However, not knowing the goal prevents us from providing the feedback to the gamer.

One possible work-around for this Unknown Goal Problem would be formulate a game of high records: players compete to achieve higher score rather than to achieve a fixed goal. While this is a very common form of gaming, it will require more study whether the unknown goal problem can be solved in general by using this form of gaming.

Controlling the Difficulty: Closely related to the unknown goal problem is the issue of controlling the difficulty level of the games that are generated from SBSE optimisations. If the resulting games are either trivially easy or significantly difficult, the gamers will soon lose interest. Whether a specific converted SBSE-game will feel difficult or not depends on a lot of factors, some of which may be entirely subjective. However, some approximation of this difficulty measure, possibly obtained by dynamic learning, will be highly useful.

Compositionality: Gaming experiences are often organised into a series of different 'stages' or 'levels' to provide the gamer with more manageable units of experiences that are not too tiring. Assuming that all SBSE tasks may not be converted into single continuous gaming experiences, large optimisation problems may have to be broken down into smaller 'game stages', the results of which will be assembled back into a solution for the original problem. Finding an appropriate way to divide a large problem into smaller components and to assemble their results back is a challenge that needs to be met.

3.3 Vision: Using Games as a Platform for SBSE

Assuming that these challenges are adequately met, we can imagine games serving as a platform for SBSE. The approach is different from existing interactive optimisation in a sense that humans are serving not as the fitness function, but actually as a complete meta-heuristic itself. Suppose we have a series of predefined conversions that produce stages of puzzle games from different input types in test data generation. Then it will be possible to point the conversion tool to a source code repository and gamers can get new levels for a puzzle game.

4 Twist Your Iguana: A Proof of Concept

Twist Your Iguana is a proof-of-concept spatial puzzle that acts as an optimisation module for a well-known evolutionary testing tool `Iguana` [9]. As a spatial puzzle, Twist Your Iguana was largely inspired by a mobile game called *feelforit* [10], for which the gamer is required to align three different arms to predetermined angles by rotating their mobile device in the space. The current orientation of the device is used as input to the game through the use of accelerometer in the mobile device. Noticing that the accelerometer input forms a multi-dimensional numerical input space, Twist Your Iguana presents a similar spatial puzzle as *feelforit*: the difference is that the gamer is required to align the controller device in a way that the corresponding input will cover a specific branch in the given code. The overview of the design is illustrated in Figure 1.

As a proof-of-concept, Twist Your Iguana only generates integer vectors of length 2. Each member of the input vector is mapped to different accelerometer in Wii Remote, a controller for Nintendo's video game console Wii that is capable of motion-control using accelerometers. Accelerometers report the spatial orientation of the motion controller by measuring the direction of gravity: each sensor reports 1.0 if the sensor is positioned upright, -1.0 if upside down. This range is mapped to the input domain for each variable in the input vector. The feedback to the gamer is given by plotting the current fitness value in red bar: the aim is to get rid of the red portion of the plot. Twist Your Iguana works successfully for toy examples as can be seen in a video presentation [11].

5 Conclusion

This paper presents a vision of formulating SBSE as gaming experiences. With the appropriate mapping, the search space for SBSE optimisation will be able

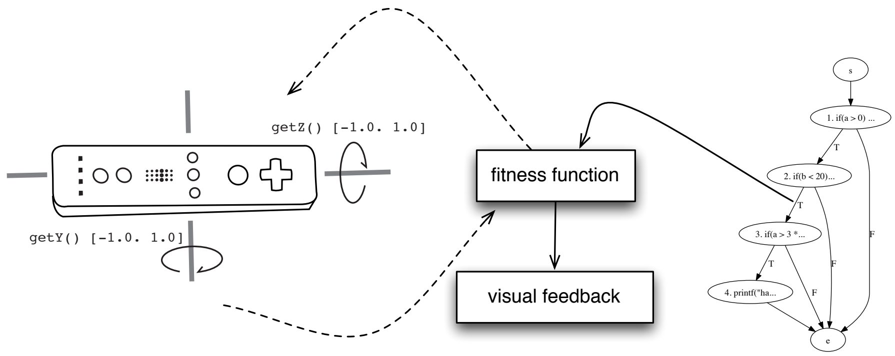

Fig. 1. Overview of Twist Your Iguana: `Iguana` generates fitness functions from individual branches. Current orientation of the controller provides continuous input to the fitness function, which is connected to the visual feedback module.

to provide an enjoyable gaming space in which the gamers will try to achieve a goal that correspond to the solution to SBSE problems. The paper also presents a proof-of-concept puzzle game that produces coverage adequate test data.

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