Automated Parameter Tuning for Steering Algorithms

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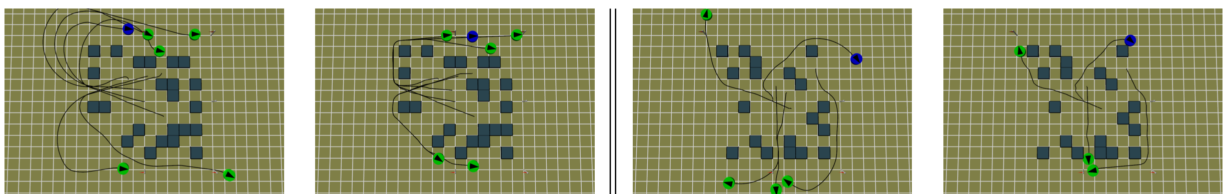

(a) Scenario I : default (b) Scenario I: max quality (c) Scenario II: default (d) Scenario II: max success

Figure 1: *Comparison of simulation traces using default [(a), (c)] and optimized [(b), (d)] parameter values. (b) was obtained for maximum quality and (d) for maximum success.*

Abstract

We propose a statistical framework and a methodology for automatically characterizing the influence that a steering algorithm's parameters have on its performance. Our approach uses three performance criteria: the success rate of an algorithm in solving representative scenarios, the quality of the simulations solution, and the algorithm's computational efficiency. Given an objective defined as a weighted combination of the performance criteria, we formulate an optimization problem in the space of the algorithm's parameters that we solve with an evolutionary-based approach. Although our framework can analyze an algorithm from many perspectives, we present two demonstrative studies: a univariate analysis that studies the effects of each of the algorithm's parameters in isolation, and a multivariate analysis that studies the combined effect of the algorithm's parameters on the objectives.

1. Introduction

Each steering method tends to be suitable for a particular class of scenarios, and makes different trade-offs between quality and performance. These trade-offs as well as the overall effectiveness of a method are usually controlled by a set of user defined parameters. Selecting appropriate values for these parameters (parameter fitting) can be quite unintuitive and requires domain experience. An automatic process that would fit these parameters for any steering algorithm would therefore be beneficial to the community. This is the main problem we address in this paper.

We present a methodology for automatically fitting the parameters of a steering algorithm to maximize a set of performance criteria related to the success rate of an algorithm in solving representative scenarios(*succ*), the quality of the simulations produced(*qual*), and the computational efficiency of the algorithm(eff). The first two metrics are examined over a representative set constructed in a fashion similar to [KWS*11]. The last metric is examined over a much different set of scenarios focused on taxing an algorithm's efficiency with orders of magnitude more agents per scenario. Our work leverages recent contributions by [KWS*11, KWFR11] which propose a characterization of the space of scenarios that steering algorithms must work with, and a set of performance metrics that can be used to statistically evaluate the effectiveness of steering algorithms. These pioneering results provide the foundation of our framework.

Our contributions can be summarized as follows:

1. We propose a statistical framework that can be used to

identify the relationship between a steering algorithm's parameters and a set of quality and performance objectives.
2. We develop an evolutionary approach to select parameter values in a multi-dimensional bounded space using the CMA-ES strategy, while optimizing multiple contradictory objectives.

2. Method Overview

Our framework is constructed as follows. First, we develop a representative set of scenarios using a form of importance sampling in accordance with [KWS*11]. We then define a set of metrics that characterize an algorithm's quality and performance as described in [KWS*11, KWFR11] and add a metric for computational efficiency. Combining these metrics linearly allows us to define scalar objective functions that balance multiple objectives. With these ingredients we can construct optimization problems in the space of an algorithm's independent parameters and analyze the performance of an algorithm from different perspectives.

We apply our methodology to two established steering approaches **PPR**: [SKH*11] and **RVO2**: [vdBGLM11]. We show that fitting optimal values to the parameters can significantly improve the performance of both algorithms over the commonly used default values with respect to an objective or weighted combination of objectives.

For each of the algorithms we first perform a uni-variate parameter analysis and study the effect of each of the algorithm's parameters in isolation. This analysis also verifies the expected inter-dependency between the algorithm's parameters, which means that to search for an optimal set of parameters we must use a simultaneous fitting approach. We address this issue by formulating a multi-variate optimization problem in the combined space of multiple bounded parameters which we solve using the Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [HO96].

3. Results

Our experiments show that parameter settings can have a significant effect on the performance of a steering algorithm. The experiments also reveal how the metrics relate to specific parameters. For example, we see that in some cases adjusting certain thresholds allows algorithms to handle more difficult scenarios, while in other cases allocating more resources for the algorithms produces higher quality results at the expense of efficiency.

Our uni-variate experiments show that independent parameter fitting does not generally find globally optimal parameter values. A multi-variate analysis allows us to simultaneously find parameter values that greatly improve the results across all metrics. The findings of this analysis can be seen in Table 1. One significant result of our work is discovering that we can improve efficiency, eff, while minimally decreasing other metrics. This is particularly true for the **RVO2** algorithm as shown in Table 1.

4. Conclusion

Our methodology can be used to identify the effects that each independent parameter has on a steering algorithm's results, as well as explore combinations of parameter values that strike a balance between competing objectives, such as scenario success and run-time performance. Applying our methodology to established steering alogrithms shows that in certain cases the fitted values of the parameters perform better than the commonly used default settings.

Algorithm	v	*succ*	*qual*	eff	*comb*
PPR	`DEF`	0.620	0.826	0.022	0.511
	`UNI`	0.748	0.880	0.046	0.603
	`MUL`	0.899	0.907	0.061	0.605
RVO2	`DEF`	0.500	0.919	0.324	0.650
	`UNI`	0.530	0.925	0.621	0.726
	`MUL`	0.537	0.929	0.637	0.737

Table 1: *Comparison of success rate(succ), quality(qual), efficiency(eff) and their equally weighted combination(comb) for both steering algorithms using: (a)* `DEF`*: default parameter values, (b)* `UNI`*: parameter values obtained using uni-variate analysis, and (c)* `MUL`*: parameter values obtained using multi-variate analysis. A value of 1 is best and 0 is worst.*

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