Work in Progress - Closing the Loop Between Simulation and Optimization in Engineering Management Education

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Abstract - **This project involves asking three sets of engineering management students to develop group projects integrating simulation and optimization in different ways and assessing their absolute and relative educational effectiveness. These approaches are: a) Ask students to repeatedly simulate, using a conventional simulation tool, Witness© in this case, a system whose design criteria are modified according to a metaheuristic, until they arrive to an acceptable design b) Directly utilizing the optimization module of the conventional simulation tool involved c) To optimize systems with a higher "social" component, i.e. those heavily affected by customer behavior, to utilize multi-agent based simulation in closed loop with the optimization algorithm. It could be relevant for those interested in: a) teaching simulation and/or optimization b) moving away from the "silo" approach and towards integrated education c) the development and assessment of applied engineering capabilities.**

Index Terms – Applied engineering capabilities, Integrated curricula design, Optimization, Simulation.

INTRODUCTION

Building on the results of two multiyear research projects on which the authors are currently involved, the project discussed in this WIP involves asking three sets of engineering management students to develop group projects integrating simulation and optimization in different ways and assessing their absolute and relative educational effectiveness.

INTEGRATED APPROACH TO SIMULATION AND OPTIMIZATION

Current curricula for various engineering tracks (electronic, mechanical, materials...) at the Carlos III University of Madrid encompass both Optimization and Simulation. Due to time limitations, introductory optimization topics covered emphasize mathematical programming techniques, supported by specialized operations research tools, that tend to be taught in isolation of the simulation, which is supported with conventional simulation tools such as Witness© or Arena© . The industrial engineering curriculum, however, allows engineering management students to devote additional effort to these topics, thus including optimization approaches such as metaheuristics that lend themselves much better to a closed loop integration with simulation. However, the stovepipe approach tradition and other hurdles such as differences among the tools used result in these topics still being presented in an isolated manner.

The current involvement of the authors in two multiyear research projects provide the framework for the project presented in this paper. An educational research project, presented in FIE08, on the assessment of practical capabilities through hands-on on-line exercises, highlighted the critical role of team projects in the development of simulation capabilities [1], [2]. A research project funded by the Spanish ministry of education aimed at the optimization of service infrastructures assignment through simulation has provided a broad foundation and detailed examples of optimization through simulation [3].

PROJECT DESCRIPTION

The current project is being carried out in a course within the industrial engineering curriculum, whose students have been exposed to the basic concepts in both simulation and optimization. They are then asked to conceptually model a system of intermediate complexity. The system selected involves different populations (leisure, business) of potential hotel customers trying to book rooms in a city that encompasses several hotels of various characteristics. The various hotels differ in objective quality, as reflected by their star rating. However, individual preferences are also considered. According to their tastes and priorities, different customers might prefer different hotels. On the other hand, each hotel has a pricing strategy whereby it switches from a low price to a high price whenever bookings for a certain date exceed a threshold. This leads to a complex interaction, in which customers "call" several hotels to inquire about availability and price and then make a choice informed by their own preferences. Hoteliers keep track of the bookings for each date and adjust their tariffs accordingly, once the established threshold is reached. Elements such as weekly and yearly seasonality by customer type, as well as probability distributions for the anticipation with which bookings are made, are included to improve fit to real life data. Each simulation must run for several yearly cycles to provide a reasonable estimate of the relative performance induced by each set of parameters.

Students are then divided in three groups to assess the relative educational effectiveness of three optimization-simulation integration approaches:

- **Conventional simulation + metaheuristic**: Students assigned to this group are first asked to build a simulation model of that system, as in the conventional approach, using a conventional simulation tool, Witness© in this case, taking all the design parameters (in this case, the three elements of the pricing strategy: low price, high price, occupation threshold) as given. They are then given increasing freedom in the choice of the design parameters. Initially they are asked to take all the pricing parameters as given, except the occupation threshold for their own hotel. When asked to "optimize" that parameter to maximize the average revenue generated in a year, students will hopefully easily realize that by repeatedly simulating several years for each of various values of that parameter they can arrive to a solution. They are then given the freedom to choose all three parameters (low price, high price, occupation threshold) of the pricing strategy for their own hotel, again with the objective to maximize the average yearly revenue. Since simultaneously maximizing three variables is not easy by trial and error, this will force students to utilize one of the metaheuristics they have been exposed to.
- **Conventional simulation + optimization module**: Students assigned to this second group are also asked to implement their simulation model in the conventional simulation tool. However, rather than manually changing the design parameters, they are asked to utilize the optimization module of the conventional simulation tool (Witness Optimizer©) and analyze the process by which it performs the optimization. This integrated optional module allows students to specify one or several adjustable parameters, as well as to choose the preferred optimization approach: exhaustive search, simulated annealing, etc.
- **Agent based simulation:** The simulated system has been intentionally selected to incorporate a significant "social" component, i.e. is heavily affected by customer behavior. Intelligent software agents are particularly well suited for the simulation of complex collective behavior and interaction, leading to models known as Agent Based Social Simulations (ABSS). In ABSS, artificial agents are placed in a computer simulated environment (with or without direct interaction with humans) and their behavior is observed and analyzed [4]. ABSS can thus be applied to less structured socio-technical systems, such as those in which a key element is the reaction of various distinct customer populations to the evolution over time of action variables such as prices. Therefore, a third, smaller group of students is asked to utilize multi-agent based simulation in closed loop with the optimization algorithm. They are asked to exploit the functionality of the Multi Agent platform used, REPAST©, to allow "customers" (each of them represented by a software agent) to exhibit a more complex and realistic behavior, such as learning from their own experience and from the interaction with other agents. Similarly to the first group, this simulation model will then be used in closed loop with the optimization algorithm to optimize the stated objective function.

Students are currently starting to build the simulation models (after instructors have tested their viability by developing pilot models). At the end of the project, the different groups will be asked to present their results to the instructors and to the rest of the groups, at which time a comparative evaluation of the educational effectiveness of each approach will be performed.

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