ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #40908

A Proposed Course of Advanced Decision Making methods for Undergraduate Students

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A proposed course of Advanced Decision-Making methods for undergraduate students

Abstract

All undergraduate engineering and engineering technology (EET) students are trained and educated in EET colleges to become future problem solvers in their own specific fields. In their own field of specialty, when they join the professional workforce, they will be faced with decision makings such as what is the best way of manufacturing a specific product, what is the most efficient way of choosing material for any specific purpose, what is the most energy efficient way of performing a specific process, what is the most economical way of designing a building while considering the optimum point of design based on inputs from different trade engineers such as mechanical, electrical, architect, and other engineers, etc.. Students more or less learn about some optimization methods during their different undergraduate courses, but a course that is focused only on some of the newer and more advanced optimization methods such as artificial neural network, data fitting and pattern recognition methods, analytical hierarchy process, agent based modeling, and game theory would be extremely beneficial to the undergraduate students that do not enter the graduate study, and will join the work force immediately after graduation. The course will help the student to be armed with extremely strong tools that help them and the companies they join, allowing students to be able to move up to the managerial level of their companies much faster. Authors recommend this course to become a required course for all EET students in different departments and engineering trades.

Introduction

Capability of critical thinking and proper decision making is the main pillar of a successful career for any engineering student. Few courses focused on different methods of advanced decision making have been developed and presented at a graduate level. The main reason for these individual courses is to help graduate students to utilize one of these techniques in their research work tailored by their master's or PhD advisors. Focusing on graduate students leaves out the opportunity for undergraduate students to become introduced and familiar with these advanced techniques. The authors of this article believe that the current professional environment needs engineers that are fully capable of advanced decision making. That helps them to make the businesses that they will be joining in the future more compatible and successful. This capability should be taught to the students before joining the professional workforce through a well-designed course. Such an undergraduate level course should be comprehensive enough to make all the different disciplines students familiar with some of the key techniques. At the same time, it should not focus on only one of them to provide an opportunity for the undergraduate students to be able to choose the method that they think may fit their future needs and study that in further

detail if it fits their professional environment. In the following paragraphs, authors underline the specifics of such undergraduate courses.

Decision-Making methods to be taught in this course.

Decision theory is divided into two major sections. These are “prescriptive/ descriptive” and “normative” methods [1]. Prescriptive decision making is mainly concerned with observing, understanding, and making conceptual models of different phenomena to set proper expected outcomes of different actions for similar people in similar conditions. This implies that people behave under some consistent rules all the time [1]. Descriptive method analysis how individual make decision [1]. Descriptive/ prescriptive types of decision making are more useful in social science environment and are concerned with how people make decisions. Observing behavior of enough people can lead to developing expected patterns for the rest of the people “https://en.wikipedia.org/wiki/Decision theory”. On the other hand, normative decision making is concerned with how people should make decisions [2]. It generally works with the assumption that people who make decisions are rational decision makers and are fully armed with the best and latest tools of decision making, so they can make optimal decisions [1]. It can be seen that, this section is more useful in engineering and economic related sciences, and therefore, more useful for engineering students. The authors’ main focus on this article is towards the latter case of the decision-making types. Normative decision making can itself be divided into three sub-sections. The first part is concerned with the topic of single objective decision-making or decision-making under uncertainty. The next part is known as multi-criteria decision analysis, and final part is known as decision support systems [3]. The first and the second category is generally more complicated and is used when graduate students start their research activities. The third category is more of a simple to use tool developed for corporate decision makers and built based on the first two categories’ techniques. Authors believe these techniques need to be taught at the undergraduate level as well, in order to help that group of undergraduate students choosing to join the work force without continuing their journey into graduate level as well. Everybody needs to be able to make correct decisions during their professional life, independent of carrying a graduate or an undergraduate degree. In the following paragraphs, authors introduce some of these techniques briefly and following that offer their proposal for structuring an undergraduate course to enable undergraduate students to be better critical thinkers, leaders, and decision makers in their after-school carriers, based on the state-of-the-art decision-making tools. Even though some of these methods are taught in different levels as an elective course mainly targeting graduate students, but to the best of the author’s knowledge, such collective course in undergraduate level does not exists, and can be a great addition to all the undergraduate engineering (and non-engineering) curriculums in different universities.

In this section, authors single out a few advanced decision-making methods that will be the core learning tools for the students in this course. It should be noted here that each of these methods can be studied in much more depth than what is targeted to be taught in this course. In fact, students will learn about these methods, do simple projects in the course, and later in their professional journey will choose which ever of these techniques has the best potential to improve

the process of the operation in their selected industries and companies. A more in-depth self-study then will lead them to much higher achievements.

Decision-making under uncertainty: In theory there are two types of uncertainty. Aleatory and epistemic uncertainty. Aleatory uncertainty is the type of uncertainty which exists in the nature of the phenomena and it is not reduceable with additional knowledge [8]. Examples of such uncertainty are fair lottery drawings and throwing fair dice. Even if you know all the lottery drawing history, still you cannot predict the outcome any better. On the contrary, epistemic uncertainty is the type of uncertainty that is due to lack of knowledge about the phenomena and can be reduced when more data is available. An example of such uncertainty is when we develop more accurate tools, we can quantify and improve our knowledge about the exact size of an object, or exact efficiency of an air fan due to manufacturing allowable tolerances. The latter type of uncertainty is the type that is in the heart of engineering and therefore, will be the main subject of this section of the course. Such analysis requires understanding of the concepts of utility function, risk attitude, etc. This is a perfect tool for all engineers specifically when performing energy modeling/prediction for buildings or different complex engineering systems.

Bayesian Theorem: Bayesian theorem is a decision-making method that is used to calculate probability of an event based on the prior knowledge of the conditions, and thereafter updating the probability of the event as one receives new information [4]. “Expected utility theory with both subjective utilities and subjective probabilities is commonly called Bayesian decision theory, or Bayesianism” [7]. This is one of the most powerful methods of decision-making that allows the decision-maker to reverse a conditional probability. Assume you have tested an engineering system, and the result of the test shows there is a malfunction in the system. The Bayesian method uses the history of similar tests, to predict what are the actual chances that there is a real malfunction in the system, based on the history of accuracy of the test itself.

Game Theory: Game theory helps decision-makers to mathematically model, study and choose strategic interaction among themselves. The main assumption here is that all the decision-makers are rational people and therefore enter the game to win. Game theory directs the main competitors in the industry to align their strategies in a way that none of them can benefit more if they deviate their strategy from the equilibrium calculated by the theory solely [4].

Artificial Neural Network: Artificial neural network is a method of artificial intelligence that uses a network inspired by the human brain and nerve system. In this method based on a large collection of the already available inter-related data set, user tries to find recognizable patterns in this data set, and further uses this pattern to predict the future events (outputs) based on some part of this data set (inputs) [9].

Agent-Based modeling: Agent-based modeling uses computer simulations of interaction among agents (people, things, etc.) to evaluate the possible outcomes based on agents’ characteristics and behavior. Each agent is assigned specific characteristics and expected different behavior in different situations. When multiple simulations are performed, the possibility of different outcomes can be quantified [10].

Fuzzy-Logic: Fuzzy logic instead of the usual true-false Boolean method, uses “degree of truth” method. In this method each event can be defined based on a percentage of truthiness or falseness. This method is a very strong tool for pattern recognition, and also controls applications. In this method, scientists first fuzzify the concept, then define rules and inference methods for the phenomena, and finally de-fuzzify the concept [9].

Analytical Hierarchy Process (AHP): Analytical hierarchy process (ASP) helps the users to make the best decisions that fit their own goals. Problems will be sub-divided into less complex problems. Solutions for each of these smaller problems will be evaluated on a pair-wise comparison, and then put back to the form of the general problem. AHP is structured based on the inputs from multi-experts each interested in one or some aspects of the phenomenon [5][6].

Course Structure and Targeted Outcomes

The first necessary achievement of developing such a course is to satisfy the ABET requirements for engineering and engineering technology students, in a way that was not previously possible for undergraduate students. For example, in line with the ABET requirements the course will increase the ability of the students to apply modern decision-making tools to solve engineering problems. Furthermore, and also in line with the ABET requirements, the course provides overall knowledge of the available tools and therefore will help the students to choose the most relevant techniques for their specific trades and design relevant systems. This course also will introduce students to a broad technical literature and how abouts of using it. And finally, the course also will solidify the students’ position as the team leaders (another target of ABET) by improving their analyzing and decision-making skills.

To satisfy the above targets, the following requirements and course structure is proposed. Except agent-based modeling that is required to be performed on its own platform (Netlogo is a free platform for agent-based modeling that is available online) almost all the other techniques that are proposed to be taught in this course can be exercised on MATLAB platform. MATLAB is a required course for all engineering trades as a programing tool, and it takes a full semester for the students to get familiar with it and be able to develop proper skills, enough to model engineering problems with it. The authors of the new decision-making course propose MATLAB as the pre-requisite for this new course. The students will be able to use their knowledge of engineering and their MATLAB skills as the starting point for fulfilling the requirements of the new course.

There will be one main instructor and multiple guest presenters from different engineering disciplines. The main instructor is the person that will teach the basics of advanced decision-making to the students. The guest speakers, each from their own specific disciplines, will come to the class once per semester to present a multidisciplinary industrial project, with their own discipline in focus, to be analyzed. Afterwards, they will not come to the class, but will be available to help students on the technical merits of the problem that they present in their office hours. The main instructor will run all classes with the target of helping students to model and based on their models to propose the best decisions for the project efficiency and success.

Students will be teamed up in such a way that there is a variety of disciplines’ representative in each team. That will help each team to have enough basic knowledge regarding all the presented

projects by different guest speakers. Students will be given instructions to make their analysis of each project with one of the decision-making techniques, at the end of semester each team represents all their solutions to the class and of course the main and guest speakers. That not only helps them to work as a team and to be able to work on multidisciplinary industrial projects, but also helps them to see all different approaches possible for the same problem. Finally, finally will be graded for the course, based on the cumulative grades of their all project and per inputs of the guest speakers to the main instructor. Of course, during the semester there will be quizzes and tests based on the basics of the decision-making methods.

Summary and Discussion:

A new course structure is presented. The course for undergraduate level is a new and unique course, tailored to improve the critical thinking, decision-making, and power of leadership of the students. This happens through getting them introduced to the best available decision-making tools (that they usually will not be introduced to if they choose not to continue their education to masters' and PhD level) while engaging in multi-disciplinary projects. The course is a new course and has not been presented before, therefore there is no data about its previous success or industry feedback regarding the students that have completed the course versus those who have not. Advanced decision-making tools are not simple tools, and each may require a semester-long course to be mastered, but the goal in this course is just introduction of such tools to the students that otherwise will not be exposed to these strong tools. Becoming masters of these technologies will be the choices that the students will take when joining the workforce.

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