Course Description

CAI4420C | Applied Decision and Optimization Theory | 3.00 credits

Students will learn how to formulate and optimize queuing, linear and nonlinear programming models. Students will understand how to apply decision-making logic and optimization techniques to artificial intelligence models and conduct decision analysis of real-world problems. Prerequisite: CAI4505C.

Course Competencies:

Competency 1: The student will demonstrate an understanding of how to model static and dynamic models where risk and preference attitudes are framed by associative factors of ignorance, bias, choice, and reward by:

1. Describing the elements of a decision model
2. Applying Bayes rule for simple inference problems and interpreting the results
3. Explaining the relationship between Bayesian rules and decision-making
4. Computing and interpreting the expected value of information (VOI) for a decision problem with an option to collect information

Competency 2: The student will determine material variables and course of action that form utility functions, calculating the combinations of stakeholder interests and expected values for potential and maximum reward by:

1. Formalizing the utility functions as rewards or prizes
2. Identifying the optimal "announced certainty" for an event in a multiagent game and the rewards that agents receive depending on both forecasts and outcomes

Competency 3: The student will be able to develop probabilistic forecasts utilizing certain and uncertain variables by:

1. Constructing mathematical models for inference and decision-making under uncertainty using linear optimization, definitive screening, and game theoretic models
2. Applying mathematical models to draw inferences from data and to make decisions
3. Distinguishing and implementing the gain from the Expected Value of Sample Information (EVSI) versus the Expected Value of Perfect Information (EVPI)
4. Collecting information that may impact the outcome of a decision

Competency 4: The student will be able to create a probabilistic model based on decision rules formed by a system representing a set of random variables and conditional interdependencies by:

1. Developing a decision problem consisting of possible actions, states of the world, and possible consequences
2. Applying the measure "goodness" of consequences with a utility function
3. Measuring the likelihood of states with a probability distribution and best action concerning the model to maximize expected utility
4. Implementing probability as a mathematical representation for uncertainty, assigning probability to events, and a probability distribution as a function of the events
5. Interpreting and accounting for situations of conflict and cooperation (including interests, values, customs, stakeholders, institutions, behavior patterns, endogenous and exogenous effects that can be interpreted as functional responses to patterns)

Competency 5: The student will be able to identify scenarios where multiple stakeholders interpret and interact with varied interests and rewards that affect the performance of the system by:

1. Creating normative analysis with formal models of choice
2. Conducting descriptive research studying how cognitive, emotional, social, and institutional factors affect judgment and choice

3. Designing and implementing descriptive interventions, seeking to improve judgment and decision-making

Competency 6: The student will be able to apply Markov Chain Monte Carlo for systematic random sampling from high-dimensional probability distributions by:

1. Estimating a target distribution by Monte Carlo sampling
2. Creating a random variable whose expected value is the desired quantity
3. Simulating and tabulating the random variable and using its sample mean and variance to construct probabilistic estimates

Competency 7: The student will be able to apply a probabilistic model that represents a set of random variables and their conditional interdependencies via an acyclic graph by:

1. Interpreting and designing Dynamic Systems, State Trees, Decision Trees, Influence Diagrams, and Hidden Markov Models
2. Designing Bayesian networks that represent a time series sequence of variables

Competency 8: The student will able to test the results of a survey or experiment to determine if they are meaningful by:

1. Optimizing survey questionnaire design
2. Implementing sampling and survey modes for unconstrained and quota- controlled sampling
3. Managing for sampling error, response rates, bias, and nonresponse
4. Designing and implementing responsible survey administration, measurement, reliability, validity, and scaling

Competency 9: The student will be able to develop a mathematical optimization to select best elements of a criterion, from some set of available alternatives by:

1. Designing optimization problems consisting of the objective function, Variables, and Constraints
2. Developing Continuous Optimization, Discrete Optimization, unconstrained optimization, and constrained optimization models
3. Describing types of optimization problems, as well as their strengths and weaknesses
4. Writing programs that find local and global optima

Competency 10: The student will be able to create Deterministic Optimization and Stochastic Optimization models by:

1. Modeling of uncertainties in optimization problems (decisions and stages, two-stage and multi-stage programs, probabilistic programming, risk-averse optimization, etc.)
2. Describing basic theory and properties of two-stage and multi-stage stochastic problems

Learning Outcomes:

- Communicate effectively using listening, speaking, reading, and writing skills
- Use quantitative analytical skills to evaluate and process numerical data
- Solve problems using critical and creative thinking and scientific reasoning
- Formulate strategies to locate, evaluate, and apply information
- Use computer and emerging technologies effectively