Description
This course focuses on the theory of information in the context of control systems. Control and stable dynamics are a general problem in which information about the state of a system plays a key role in achieving stability and operational quality. The cybernetic framework is used to understand how computerized control systems such as embedded controls and management information systems are crucial to the management of the modern world. The general theories will be used in specific example systems where students will gain experience designing and implementing computerized feedback control. The principles of cybernetics are universal so that students will be able to transfer their understanding and skills to any real-world domain.

Version: 06-05-12

Student Learning Goals (SLGs) for the Course

1. Can articulate and define, with examples, the principles of systems science
2. Demonstrates understanding of the formal theory of information
3. Can articulate the role of information in general systems
4. Demonstrate the basics of first-order cybernetics in a model system
5. Can relate this view of information with common uses of the term, especially in computer science and information science
6. Demonstrates the ability to build a computational model of a control system and show its behavior under varying inputs

Student Learning Outcomes (SLOs)
The SLGs for the course will contribute to the following program SLOs:

- An ability to apply knowledge of theoretical foundations in computer science [SLG 2];
- An ability to use current techniques, skills, and tools necessary for computing practice [SLG 6];
- An ability to analyze a problem, to assess and articulate its requirements, to design, to implement, and to evaluate a computer-based system [SLGs 4 & 6];
- An ability to communicate effectively in both oral and written forms [SLGs 1, 3, & 5];
- An ability to participate effectively in team projects [SLG 6];
- Recognition of the need for and an ability to engage in self-directed learning and continuing professional development [SLG 5].
UWT Student Learning Goals
UWT’s strategic SLGs that this course contributes to:

- Inquiry and Critical Thinking [SLGs 2, 4, & 6];
- Communication/Self-Expression [SLG 1, 3, & 5].

Topics Covered:

Information theory and cybernetics in the context of general systems theory
The universality of systems theory

Information theory background
- Historical and Mathematical Grounding
- Information theory in different disciplines
- The difference between information and meaning
- Information as news of difference

Control theory background
- Historical and Mathematical Grounding
- Cybernetics in different disciplines

Information Feedback and Control
- General theory – the governor
- Applications
- Limits and dangers – when systems go out of control
- Computational problems and solutions

Types of Cybernetic Systems
- Simple feedback
- Feedforward and anticipatory systems
- Adaptive control systems
- Hierarchical and distributed control systems

Modeling Cybernetic Systems
- The system identification problem
- Proportional, Integrative, Derivative (PID) control
- Anticipatory and Adaptive control models
- Hierarchical control models

Cybernetic Algorithms
- Embedded controllers
- Adaptive agents
- Enterprise management and social governance
Work Assignments, Discussions, and Assessment

There will be three main kinds of work activities undertaken by the students. These are:

- In-class, participatory discussions of the assigned readings;
- Research on a student-chosen sub-topic of interest, with a research report given in the last week of class;
- A small group project to develop a model cybernetic system

In addition there will be a mid-term examination to evaluate how well students understand the concepts (10% of grade).

Students will be evaluated for the level and quality of their participation in the in-class discussions (20% of the grade). Students will be expected to generate interesting questions and insights from the readings or lectures. The professor will keep a tally of the number of times a student initializes a meaningful discussion on such questions or insights. Students who respond in the discussion will also be given credit for their participation.

Each student will choose a sub-topic from the above list, develop a reasonable reading set with the consultation of the professor, and produce an insightful report on that topic for presentation to the class in the last week. The paper should relate the subject to the principles of systems science and particularly to the subjects covered in the course. Assessment will be on the basis of the quality of the topic chosen, the reading list developed, the quality of the report document, and the quality of the final presentation. This activity will account for 40% of the final grade, broken down as: 5% - subject choice; 5% - reading list; 20% - report; and 10% - presentation.

The small group project will involve a group of no more than 3 people developing a computer model of a cybernetic system. There will be several system models to choose from and the choice of languages will be up to the students (Java suggested). The project will involve analysis of the control problem, design of a simulation, implementation of the simulation, running the simulation and collecting and displaying data from the simulation under varying environmental conditions. This project will account for 30% of the final grade. Each member of the team will be assessed separately (10%) for their specific contribution to the project’s success. The group as a whole will be assessed (20%) for the quality of their analysis, design, implementation, and data collection/display. These projects will be presented and demonstrated during finals week as a class symposium. More information will be forthcoming regarding models and requirements.

Readings


<table>
<thead>
<tr>
<th>Week No.</th>
<th>Subject(s) Covered</th>
<th>Reading Assignments</th>
<th>Work Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Principles of Systems Science Applied to Cybernetics</td>
<td>M&amp;K Chapter 1 Wikipedia – Information Theory and Claude Shannon</td>
<td>Develop three questions from the readings or lectures for class discussion (these will be turned in at the first class meeting and discussed at the second)</td>
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<tr>
<td>3</td>
<td>Information Theory Basics</td>
<td>M&amp;K Chapter 7 through Quant Box 7.2</td>
<td>Consult with professor on research topic to develop reading list. Three questions for discussion, turned in first class. Form groups for modeling project.</td>
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<tr>
<td>4</td>
<td>Information Theory Mathematics</td>
<td>Shannon, Parts 1 &amp; 2 (above URLs) Rest of M&amp;K Chapter 7</td>
<td>Read the model project requirements and develop three questions about the project. Develop three questions about information theory for discussion.</td>
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<tr>
<td>5</td>
<td>Mid-term exam (first class) Information Theory and Application in Systems</td>
<td>M&amp;K Chapter 8</td>
<td>Write a short critique of M&amp;K chapter 7 thus far covered. Discussion in second class session. Turn in a proposal for the</td>
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<tr>
<td>Week</td>
<td>Topic</td>
<td>Chapter</td>
<td>Additional Information</td>
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<td>6</td>
<td>First Order Cybernetics Systems – Feedback Control</td>
<td>M&amp;K Chapter 9</td>
<td>Turn in draft of research report outline. Three questions from the reading. Turn in project analysis document.</td>
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<tr>
<td>7</td>
<td>First Order Cybernetics – Feedforward and Operational Controls</td>
<td>M&amp;K Chapter 9</td>
<td>Three questions. Turn in project design document. Turn in research report draft revision (if needed).</td>
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<tr>
<td>8</td>
<td>Coordination Cybernetic Systems – Logistical and Tactical Systems</td>
<td>M&amp;K Chapter 9</td>
<td>Work on implementation. Discussion this week will allow groups to share a preview of their projects and discuss choices.</td>
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<tr>
<td>9</td>
<td>Strategic Cybernetic Systems with Examples</td>
<td>Model building TBD</td>
<td>Three questions. Turn in research report and project write up.</td>
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<tr>
<td>10</td>
<td>Summary of the Topic and Individual Research Reports</td>
<td>No reading</td>
<td>Presentations – about 20 minutes each.</td>
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<tr>
<td>11</td>
<td>Project Reports</td>
<td>No reading</td>
<td>Presentations during finals period – about 25 minutes each.</td>
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