IT 894 – DESIGN AND INVENTIVE ENGINEERING

Fall 2006

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Lectures: Friday, 4:30 p.m. – 7:10 p.m.

Office Hours: Friday, 1:00 p.m. - 4:00 p.m.

Textbook: No single textbook is recommended. The list of readings related to the individual topics is provided in the course outline

Final Exam: Final exam will be comprehensive.

Course Requirements:

1. Active participation in all classes.
2. Three home assignments.
3. Presentation in the class.

Grading Scheme:

1. Three home assignments - 30 %.
2. Presentation - 40 %.
3. Final exam (take home exam) - 30 %.
MAIN TOPICS

1. **Fundamentals** (4 lectures)

   1.0. *Introduction*

   1.1. *Transdisciplinarity*

   Knowledge evolution, contradictions and solutions, fusion versus transdisciplinarity, transdisciplinarity, transdisciplinar knowledge, Design and Inventive Engineering.


   1.2. *Transdisciplinary Engineering Creativity: Three Dimensions*

   1.2.1. *Creative Class*

   Evolution of a society, transformation, creative class descriptors and components, regional growth and driving forces, creative community, Memphis principia, creative class values, social and creative capital.


   1.2.2. *The Medici Effect*
The Medicis, the Medici Effect, intersection, intersection of disciplines, creative versus innovative ideas, directional versus intersectional ideas.


1.2.3. The Renaissance Man

Renaissance, discoveries, key figures, paradigm change, Renaissance versus Information Technology Revolution, Leonardo da Vinci, his life, art and scientific contributions, da Vincian principia: Curiosita, Dimonstrazione, Sensazione, Sfumato, Arte/Scienza, Corpolita, Connessione, principia and design science, inventions, methodological reflection, vision and impact.


1.3. System Designing (September 14, 2006)

System; engineering design process; design representation space; symbolic and numerical attributes; design concept and detailed design; conceptual and detailed design process stages, various models; conceptual design paradigms; routine versus inventive design concepts; categorization of designs; generation of design concepts: holistic view, inventive designing and its four generations.


1.4. System Architecting (Dr. James Martin) (September 14, 2006)
History; architecting versus engineering; science-based and art-based methods; architecting paradigm; complexity and systems; systems approach; architect; waterfall models.


1.5. Design and Inventive Engineering

Science and engineering science; history of engineering; engineering design: science or art; design engineering; inventive engineering; routine versus inventive design; IT and design paradigm change; knowledge and knowledge paradigm in design; general methodology; methodics, design support tool development; why inventive engineering.

1.6. Engineering Method

Engineering optimum; the principal rule of the engineering method; heuristics; engineering state of the art; engineering heuristics: rules of thumb and order of magnitude, factors of safety, attitude-determining heuristics, risk controlling heuristics, resource allocation heuristics; definition of engineering and engineering design; engineering versus applied sciences; engineering method.


1.7. Heuristics and Decision Rules: from Praxiology to Computer Science

Several perspectives: from philosophy to computer science; sources of heuristics; praxiology fundamentals, directives and examples; Koen’s heuristics and system architecting; engineer versus architect;
architecting heuristics; psychology, heuristics and design styles; heuristics versus decision rules; instructor’s heuristics.


2. Design Engineering (4 lectures)

2.1. **Formal Designing** (3 lectures)

2.1.1. *Al in Design* (Professor John Gero) (September 29, 2006)

Designing: a definition, a transformation model; function, design description, behavior, evaluation, synthesis model, design process and its components and stages, design activities, representation subspaces, routine, innovative and creative designing.


2.2.6. **Evolutionary Designing** (Dr. Rafal Kicinger) (October 6)

Fundamentals of evolutionary computation, design representation spaces, conceptual process as an evolutionary process, integrated approach to inventive design, integrated design support tools, lines of evolution and fitness landscapes in inventive design, Inventors 2000 and 2003, morphogenesis, generative design, creative design, generative representations, cellular automata, distributed evolutionary design, island-model evolutionary algorithms, multi-population evolution.


• 2.2.1. Designing as Search


• 2.2.5. Constraint Search
Constraints and their classification, constraint search and its basic types, acquisition of constraints, constraint search-based system for conceptual design, examples of constraints, computer concept generation and structural examples.


2.3. Design Evaluation

Evaluation in engineering design, various definitions, classical multicriteria evaluation (Churchman and Ackoff): assumptions, procedure, examples, engineering multicriteria evaluation: assumptions, procedure, industrial examples, multicriteria utility-based evaluation, evaluation knowledge and its acquisition, knowledge-based evaluation approach, evaluation criteria and their identification, evaluation criteria and evaluation attributes hierarchies, evaluation knowledge-based system: basic assumptions, architecture, operations, example of actual implementation, research directions.


2.1. **Design Theories** (1 lecture)

2.1.2. *Axiomatic Design Theory*

Design process, design parameters, functional requirements, decision making in design, design axioms, the independence axiom, the information axiom, history of axioms in science and engineering,
problem definition, functional requirements in the context of innovation, house of quality in manufacturing, hierarchies of functional requirements and attributes, constraints and their categorization, axiomatic design theory: two axioms, theorems and corollaries, uncoupled, coupled and decoupled designs.


### 2.1.2. Inferential Design Theory

Inferential learning theory, design process, conceptual design process, conceptual design paradigm, applicability of the IDT, basic methodological assumptions, design knowledge transmutations, transmutations as inference, individual transmutations and their engineering interpretation, examples of transmutations, research directions and building design support tools, CREDO - a computer tool for conceptual design and its practical use.


### 3. Inventive Engineering (2.5 lectures)

#### 3.1. Brainstorming

Group problem solving, psychology of problem solving, associations, procedure, group organization and optimal design, IdeaFisher - a tool for brainstorming and its use in the class.
3.3. Synectics

History, definition of synectics, invention design group, creative problem solving, psychological aspects of ideation, synector and synectics group, creative mechanisms: making the strange familiar and making the familiar strange, analogies: personal, direct, symbolic, fantasy, procedure, industrial examples, use of MindLink software.


3.4. Morphological Analysis

History, concept of atom, related developments in various countries, systems analysis versus morphological analysis versus stochastic form optimization, methodological assumptions, problem formulation and pegging, morphological field/box/table versus knowledge representation, synthesis, generation of concepts, procedure, stochastic simulation of concept generation process, building morphological table, computer tools, examples of inventing joints in structural engineering.

3.5. TRIZ and Directed Evolution (Ms. Alla Zusman and Mr. B. Zlotin) (November 10, 2006)

History, concept classification, Altschuller and his thoughts about innovative design, psychological inertia, main assumptions, substance-field engineering system, minimal engineering system, substance-field analysis, contradictions and their classification, identification of contradictions, eight rules of engineering system development, inventive tricks and their collection, design procedure and its stages, ideal solution, elimination of physical contradictions, schools of inventors, computer tools, patented inventions.

- Clarke, Dana, TRIZ: Through the Eyes of an American TRIZ Specialist, Ideation, 1997.

3.6. Computational Creativity (Professor John Gero) (November 3, 2006)

4. Design Research Frontiers (4.5 lectures)

4.1. Inventive Design in Practice (Drs. Frank Berte and Kalu Uduma) (1 lecture)
Dr. Frank Berte: From MIT-learned analytical skills to creative problem solving, sailing boats and novelty, how new design concepts emerge, are tested and evolved.

Dr. Kalu Uduma: Car safety requirements, crash engineering, crash avoidance design concepts, present design practice, applications of inventive engineering, novel side collision protection devices, future impact protection systems.

4.2. Constructive Induction

Selective and constructive induction, primary and constructed attributes, semantic interpretation of constructive attributes, engineering creativity as a constructive induction process, emergent concept and its semantic interpretation, applications of constructive induction in inventive design.


4.3. Situated Learning and Design (Professor John Gero) (December 1, 2006)
4.4. Creative Company (Dr. Chris Luebkeman)
4.5. Bio-inspiration in Design: Conceptual and Computational Inspiration and Generative Representations (Dr. Rafal Kicinger)
4.6. Collaborative Design and Virtual Studios, (Dr. Mary Lou Maher)
4.7. Design for Robustness, (Kenneth Shelton)
4.8. Ontologies in design
4.9. Design knowledge acquisition

5. Project Presentations (1 lecture)