Emergent Designer

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Motivation

• Paradigm change from the creationistic to the morphogenic evolutionary design paradigm
• Industrial needs to increase/maintain market share through the “production” of novel and “better” designs in shorter time period
• Shifting focus from the numerical optimization to various holistic design approaches addressing issues of novelty, constructability, security, etc.
Design Paradigms

- **Creationistic design paradigm:** a human designer creates at most several design concepts using his/her background knowledge and “intuition”
- **Morphogenic evolutionary design paradigm:** a human designer uses a computer tool to generate a line (or lines) of evolution of design concepts, hundreds or thousands of design concepts (and final designs) are produced
Morphogenetic Evolutionary Design

• Inspiration from Nature
  – Genetic plans – *rules* for growing complex organisms rather than the organisms themselves
  – Morphogenesis – *developmental* process of building organisms from the plans

• It does not encode complete design concepts but rather *rules* how to construct these designs

• Design concepts and design processes can be represented using various models of complex adaptive systems
Morphogenic Evolutionary Design

“Morphogenic evolutionary design is the systematic generation and evaluation of representations of engineering systems, or their parts, whose form and function achieve stated objectives and satisfy specified constraints. It is done using the mechanisms inspired by the processes of developmental biology and evolution.”
Morphogenetic Evolutionary Design: Generative Representations

- Inspired by morphogenesis
- Utilize simple models of complex systems to represent steel structural systems in tall buildings (1D and 2D cellular automata) and design processes (evolutionary algorithms)

- Two parts:
  - encoding of the ‘design embryo’
  - encoding of a ‘design rule’ which is applied to the design embryo to develop a design concept from it
Generative Representations: Design Embryo

A design embryo: an ordered set of cell values representing an initial configuration (here one-dimensional) of structural members (e.g. types of wind bracing, beams, columns) from which a design concept is developed.
Generative Representations: Design Rule

- A design rule: a formal description of a transformation changing the current configuration of structural members into a new configuration.
- Such transformation defines a unit time step.
Generative Representations: Developmental Process

A wind bracing system:

Development of a wind bracing system:

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Morphogenic Evolutionary Design Paradigm

A large number of design concepts is produced and:

– Only one is ultimately used, although a larger set of design concepts can be finally considered, e.g. the entire Pareto front

– Remaining concepts are discarded or considered a by-product, an intellectual property to be protected and used

– Remaining concepts represent a body of potential design knowledge in the form of evaluated examples
Emergent Designer

• A computer tool implementing morphogenic evolutionary design
• Research and design support tool for the generation and optimization of design concepts and comprehensive analysis of the design processes
• Developed by Rafal Kicinger in the IT&E School at George Mason University in cooperation with:
  – Tomasz Arciszewski - CEIE Department
  – Kenneth De Jong - CS Department
  – Timothy Sauer - Mathematics Department
Comprehensive Analysis: Acquiring Design Knowledge

• Acquisition of design rules (inductive learning) modeled by simple cellular automata rules
• Statistical analysis of lines of evolution
• Complex adaptive systems analysis of lines of evolution
• Visualization of lines of evolution
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