



Industry/University Cooperative Research Center for e-Design Research Portfolio-Current Projects

University of Pittsburgh

A TIE Research Program on e-Design for Design for Supply Chain

Researchers: *Drs. Kim LaScola Needy, Bryan Norman, Ricki Ingalls (OSU¹-CELDi²), Scott Mason, (UA³-CELDi²)*

1-Oklahoma State University, 2-Center for Engineering Logistics & Distribution (CELDi), 3-University of Arkansas

This research addresses the problem of how to effectively synchronize Product Design (PD) and Supply Chain (SC) design for new and existing products resulting in not only a good product design, but a supply chain that is costs effective, minimizes lead time and ensures quality. There are three major questions this research will study: (1) How robust is the SC to product changes? (2) What is the relative importance of the PD and SC design on the product's success and profits? (3) How does the performance of the product and the associated SC design differ for the simultaneous and sequential approaches to the PD and SC problem?. Answers to these questions and the resulting analytical balancing of PD requirements and their SC impacts will help managers broaden and enhance their decision support mechanisms. In addition, a test platform with a user friendly interface will facilitate practitioners incorporating these complex models into their decision support systems. In summary, this research will help fill the existing gap of understanding the complete relationships and tradeoffs between optimal product and supply chain design requirements.

Development of Virtual e-Design Training Tools for the Energy Industry

Researchers: *Drs. Michael Lovell, Kenneth Sochats*

The long-term objective of the present project is to develop new and highly intelligent virtual instructional tools for the power and energy industry that will attract and train the next generation of leaders in the field. The shorter term goal of this project is: to demonstrate the feasibility of our approach by providing a visual, interactive tour of the containment interior of a pressurized water reactor that can be used for undergraduate, graduate, and industry level instruction. We initially plan to construct a computer based interactive intelligent virtual model of the interior of the containment of a nuclear reactor. The virtual model will contain an exact representation of all of the relevant components inside containment of the reactor (safety systems, pumps, steam generators, pressurizer, motors, valves, sensors, etc.) The virtual interactive game technology based model is differs from fly-through models in that: 1) It is composed of active objects. 2) The virtual world in which the model is built has physics, 3) Users and objects can change other objects and the bases of operation of the model itself, 4) The virtual model is Internet based, 5) Faculty, student and subject matter expert users can take on active (participant) or passive (observer) roles on line interacting with the model and/or each other. 6) The model can be used to facilitate evaluation.

Tools and Artifacts in Innovative Design

Researchers: *Drs. Michael Lovell, Christian Schunn*

Engineering design is not a purely cognitive process. Successful design engineers strategically move from ideas to completed designs through refined, physically-supported imagery (artifacts) and tools, among which the e-design tools and artifacts play important roles in supporting creativity and innovative ideas. In order to build a fundamental understanding of the cognitive processes underlying the role of e-design tools and





artifacts in the innovative design process, we are conducting research to find the relationship between the degree of use of *e*-design artifacts/tools and innovative design outcomes. The objectives of our research are, 1) To determine the relationship between *e*-design tool usage and innovative design outcomes, 2) To develop novel *e*-design tools that can be woven into the fabric of engineering practice and education.

Protecting Intellectual Property in Collaborative Design

Researchers: *Drs. José Carlos Brustoloni, Yan Wang (UCF)*

This project is developing Web protocol, server, and browser modifications that enable secure posting and retrieval of documents with usage controls. Our objective is to harden existing software-based DRM systems by integrating them with hardware-based usage controls. We implement the latter using Trusted Platform Modules (TPMs). TPMs are low-cost secure coprocessors available in an increasing number of computers from Lenovo, Dell, HP, and other manufacturers. In our approach, no modifications are necessary in applications used for authoring and displaying usage-controlled files (e.g., OpenOffice and xpdf). The hardware-based controls thwart attacks against software-based DRM by ensuring that only trusted applications can open usage-controlled documents. This protection adds little overhead, and user studies in the lab suggest that the system is easy to use even by untrained users.

University of Massachusetts Amherst

Extending an Engineering Design Optimization Ontology for Supporting Reasoning and Multidisciplinary Constraints

Researchers: *Drs. Sundar Krishnamurty, Ian Grosse*

As designs become more elaborate, complications arise when developing products throughout disciplines. The evolved OPTEAM will allow designers to capture modeling knowledge when developing a design, as well as share it with other disciplines. While sharing between disciplines may not always happen as designed, the ability to impose cohesiveness across descriptive boundaries can be realized through the application of logical rules on an instantiated knowledge base. OPTEAM is a knowledge capturing tool originally developed within the Protégé environment to capture both engineering design optimization and engineering analysis modeling knowledge. The extended first-order predicate logic capabilities of the OPTEAM tool allow for the introduction of many new methods to the tool. First-order logic will now allow the knowledge acquisition process to be guided by identifying when knowledge has been improperly instantiated, therefore guiding the acquisition process. First-order logic will also now allow assertions to be made on the instantiated knowledge base, allowing for knowledge to be easily instantiated through logical operators, and facilitating the knowledge capturing process.

Distributed Multidisciplinary Decision Support

Researchers: *Drs. Ian Grosse, Sundar Krishnamurty, Jack Wileden*

The proposed project aims at providing a platform which facilitates decision methods in a distributed, multidisciplinary engineering environment. Building upon and extending the *e*-Design Distributed Process Framework, we propose to develop a web-based decision support tool that provides designers and decision makers with a means to effectively evaluate design alternatives. By utilizing the power of the semantic web and ontologies, this tool will connect distributed teams through a design environment that facilitates consistent communication. The decision tool will be able to implement various decision methods and guide engineers through the necessary procedure. Additionally, the decision tool will be able to capture information about each engineer's knowledge, experience, preferences, and confidence with respect to the proposed design change.



The decision maker can then review the group's recommendation on the design change and each individual engineer's judgment. This approach models and documents design decision within the ontological framework so that the knowledge and rationale behind decisions are both transparent and reusable. The resulting decision models are flexible and adaptable to changing product requirements or could be reused for similar projects. This web-based decision support tool will be compatible with the e-Design Distributed Framework and assists in the evaluation of design alternatives to aid in the decision-making process.

University of Central Florida

A Conceptual Modeling Multi-Criteria Analysis Environment for User-Centered Design

Researcher: *Dr. Christopher D. Geiger*

This research project involves the development of a multi-criteria analysis tool that can be used to: (1) reduce the set of design criteria that must be considered by a designer and (2) effectively assess product (or system) design criteria. The proposed design tool, which is envisioned to be most useful during the conceptual design phase, will assist designers in creating design alternatives that are driven by user-centered design (UCD) considerations and tradeoffs among conceptual functional design criteria (DC). The output from this tool will be the identification of the most critical UCD factors for achieving the mission (high-level requirements) of the product/system. Furthermore, the resulting design criteria can be used to develop design requirements that drive the next phases of preliminary and detailed design ultimately helping to accelerate the transition from design conceptualization to design realization.

4D Geometry Compression

Researcher: *Dr. Yan Wang*

This project aims at efficient information processing on networked devices, considering limits of network bandwidth and computation resource. We use a generic data structure to store both mesh and volume data. Both geometry and topology information are stored and compressed uniformly and can be synchronized. We extended our previous hybrid 3D geometry animation compression result to consider volume mesh data, which is an important extension of the 4D LWT method. We are developing a truly scalable compression algorithm which allows various attributes such as isovalues, engineering attributes, color and audio to be appended to the current compression methodology via the Lifted Wavelet Transform (LWT). Our implementation is based on a generic "box" mechanism, where each distinctive data set within a given animated stream corresponds to a set of box data structures, thus allowing for direct integration with LWT compression, which inherently allows for extensibility.

Fundamental Research on Interoperability

Researchers: *Drs. Yan Wang, Jack Wileden (UMass)*

Like all modern cooperative enterprises, *e*-design depends crucially on how well heterogeneous collections of computer-based tools and data can be made to work together. Yet existing approaches to interoperability have numerous shortcomings: they are generally *ad-hoc*, low-level, narrowly targeted, difficult to use and prone to produce erroneous interactions. Our intent is to improve the quality, expand the scope and broaden the applicability of interoperability theory and practice. Efforts directed toward achieving this objective are organized around two interrelated threads of research. One thread is focused on developing and evaluating *fundamental theoretical foundations* for understanding, designing, implementing and assessing interoperability mechanisms. The other thread is aimed at producing improvements in *automated support for generating implementations* of interoperability mechanisms, including existing mechanisms as well as new mechanisms



resulting from the first thread. Each of these threads will build upon recent successes in computer science research, where enriched theoretical models and enhanced implementation techniques have led to improvements in both foundations for and automation of interoperability among software modules at both programming language and application data levels.

Virginia Tech

e-Design for Friction Stir Welding and Processing

Researchers: *Drs. Janis Terpenny, Venkat Allada, Rajiv S. Mishra (University of Missouri Rolla)*

To ensure successful implementation of Friction Stir Welding (FSW) and development of new technologies based on friction stir concept, the CFSP (Center for Friction Stir Processing) industrial sponsors have requested that *e-Design* methods be included in the ongoing projects to assure availability of latest design approaches to enhance diffusion of friction stir based technologies. A decision support tool is needed to enhance the diffusion of FSP technologies and aid designers in evaluating fastening/joining design alternatives against requirements and costs. In this project, an ontology is built to capture and manage the data and data relations in the Design for Manufacturing (DFM), and to facilitate reasoning and querying the relative design alternatives. Based on the design alternatives retrieved from the ontology, the decision support tool is now in development to help designers choose the best design alternative after trade off among several economical and technical criteria, such as total cost, component accessibility, tool fouling, etc.

Facilitating Effective Communication in Interdisciplinary Design Teams

Researchers: *Drs. Lisa McNair, Maura Borrego, Marie Paretti, Janis Terpenny*

When asked about the biggest obstacle to effective teamwork and research collaborations, many engineers, scientists and mathematicians say it is the terminology differences across fields. For example, one term might have one precise meaning to statisticians and a very different but equally precise definition for biologists. When working in interdisciplinary teams, people must learn not only new terminologies and practices, but also be able to address varying disciplinary standards and practices. However, there is evidence that at least when the team members are trained in very different fields, language issues are representative of much deeper conceptual differences between the disciplines and their world views. We are researching cognitive linguistic analysis to determine the ways to facilitate interdisciplinary communication and build instructional tools for engineers in industry and education.

iCollab – Real-time Infrastructure for Collaborative e-Design Services

Researchers: *Drs. Nicholas F. Polys, Denis Gračanin*

This project will explore the performance impacts and tradeoffs in a collaboration service for *e-Design* applications. While there are numerous architectures and technologies that support multi-user information spaces, they are typically geared to social or scientific pursuits. We propose to examine the engineering and design process in order to understand the requirements for collaboration and real-time communication in *e-Design*. The profile of *e-Design* activities will be mapped to a network protocol and virtual world manager that can provide the highest Quality-of-Service (QoS). Multi-platform clients can connect to iCollab and participate in model browsing, building, modification, and annotation for example.



Industry/University Cooperative Research Center for e-Design Research Portfolio-Completed Projects

University of Pittsburgh

Global Sourcing Decision Models

Researchers: *Drs. Bopaya Bidanda, Larry J. Shuman*

This project researched, investigated and analyzed decision models to develop a hybrid model utilizing analytical models in the Management Science and Operations Research literature. The integration of continuous and discrete spaces under qualitative and quantitative criteria was established by utilizing two well-known decision making tools, namely mathematical modeling and Analytic Network Process (ANP). The results from mathematical model (minimum cost considerations) and ANP (minimum risk & maximum opportunity) are integrated in a multi-objective optimization model. This research brings to fruition a process to overcome the challenge of handling multidimensionality incorporated in the location and distribution selection processes in global supply networks. Hence, a hybrid model is proposed to support corporations in their global sourcing strategies.

Design for Supply Chain

Researchers: *Dr. Kim LaScola Needy*

This project developed a process for *Design for Supply Chain* - that reduced manufacturing, logistic support, distribution, and sales expenditures. Pertinent information is drawn from each of the organizational disciplines and marshaled to provide vital product data. Another objective was to elevate the supply chain to the level of a design and development partner to create a ripple effect of benefits consistent with an OEM's primary objectives - quality and time to market. It also resulted in elimination of the "bullwhip effect" (cascading rise in inventory and pending work-in-process, financial bottlenecks due to unanticipated changes to product design). It supports not only *e*-product design, but also redesign associated with obsolescence, process improvements, and design changes in general. It leads towards the development of a Design for Supply Chain (DFSC) process. This process will result in a proactive approach to *e*-product design and design change allowing impacts to the supply chain to be predicted in advance and resolved more quickly and economically.

University of Massachusetts at Amherst

Application of Distributed Process Framework for e-Design

Researchers: *Drs. Ian Grosse, Sundar Krishnamurty, Norm Sondheimer, Rui Fernandes, Paul Witherell*

Significant expenditure and effort is devoted to the never ending search for reduced product/project development lifecycle time and increased efficiency. However, when projects expand to involve more than one organization or discipline, processes tend to become significantly less efficient. Thus, project or system requirements determined at a high level do not directly specify performance requirements of system components. The decomposition of requirements can lead to a situation where the link between the detail technical requirements to the original requirements becomes unclear. With the optimization and engineering





analysis (ONTOP and ONTEAM) we have shown that using a cohesive ontological structure, knowledge can be captured and searched within the context of well defined engineering activities. We believe that enhancing this knowledge framework to include project, system, and product ontologies we can create contextual links between low level (detailed) engineering knowledge to high level system requirements. The links between individual engineering tasks and project requirements will provide means to validate performance against high level requirements.

e-Design Methods and Tools for Facilitating Product Innovation

Researchers: *Drs Ian Grosse, Sundar Krishnamurty, and Jack Wileden (UMass)*

Designers need a detailed understanding of the problem at hand along ability to evaluate a large pool of candidate design concepts. Function-based design is a methodology in which a product is described by the overall function or service it provides. This function is decomposed into a hierarchical set of subfunctions based on the flow of energy and forces, materials, and information through the system. By focusing on the functions individual components, sets of components, or subassemblies provided and how these functions are related to overall product performance, engineers are better able to overcome some of the psychological inertia engrained in them by past design solutions, ‘think outside the box’ defined by the traditional design space and arrive at innovative solutions. Our research plan is to develop the necessary design knowledge representation to support innovation. A knowledge architecture, based on the Distributed Process Framework, describing the design process will be used to deploy innovation methodologies. The initial design framework will be based on function-based models and the TRIZ methodology to generate design suggestions. We will identify the key concepts in the domains of product functional decomposition and problem solving cause-and-effect logic models, identify the relationships between these concepts, identify the properties of these concepts, and develop and implement a consistent product ontology that supports the representation of this knowledge.

Improving Interoperability of Data and Tools in an e-Design Environment

Researchers: *Drs. Jack Wileden, Ian Grosse*

This project is directed toward simultaneously developing rigorous foundations for reasoning about interoperation and implementing prototype tools for applying those foundations in the specific setting of *e*-design data, tools and ontologies. The rigorous foundations are being based on modern concepts in programming language research, notably recent advances in programming language type theory. The foundations we are developing will provide the sound semantics required to permit accurate analysis of the correctness and safety (and, later, of other aspects such as the security) of any proposed interoperation of *e*-design data, tools or ontologies. Our foundations work is intended to be incremental and informed by our simultaneous work on prototype tools. The prototype tools will demonstrate how *e*-design data, tools and ontologies can be safely and seamlessly integrated. Ideally, our work will be centered on interoperation problems faced by, or interoperability approaches currently used by, our industrial partners. We expect that both the foundations and the prototype tools will be incorporated into our teaching as they mature.





University of Central Florida

Modeling and Simulation of Cost Considerations throughout the Design Process

Researchers: *Drs. José Sepúlveda, Luis Rabelo, Nabeel Yousef*

This project approach builds on research done in the development of a more flexible “System of Systems” e-Design environment that will react to dynamic daily changes and communicate between different management information systems. The purpose of this research is extending cost reduction to the enterprise level providing a mechanism for the development of cost-based performance measures for the activities, restructuring the activities to be integrated with each other across the systems of the supply chain, driving future profits by creating newer strategies and recognizing the profitable products and services and eliminate the non-profitable ones. This project addresses Business Intelligence (BI) and the cost analysis as an enabling technology element of the systems engineering with specific focus on integration and estimation of cost (not just sum of the individual parts) within an evolving system-of-systems environment. Management of sensitivity to cost, schedule, and technical performance are evaluated to achieve mission success with optimized cost.

Virginia Tech

Global Collaborative Engineering Design Test-Bed

Researchers: *Drs. Jan Helge Bøhn (TU Darmstadt and Virginia Tech), Reiner Ander*

This project is concerned with the development of a test bed to support research into global collaborative engineering design and product development. The purpose is to investigate, and to propose and demonstrate solutions to the problems associated with product development and engineering design in a global environment. Particular concerns include (1) Maintaining effective engineering design databases in a high-throughput, high-latency network environment without depending on conventional database synchronization (2) Engineering design processes that accommodate teams that are globally distributed even down to the lowest sub-team level, and that operate within the “follow the sun” paradigm.

Global design teams that overcome these challenges will significantly reduce their time to market, reduce rework, and improve their understanding of customer needs. This project provides access to a unique, highly cost-effective, truly global test bed where industry members can explore, test, and assess next generation practices for deploying global collaborative engineering design methodologies, hardware, and software systems, without jeopardizing their own production systems.

CP³: Comprehensive Product Platform Planning

Researcher: *Dr. Janis Terpenny*

CP3 is a structured method with the objective of identifying feasible product modules and platform alternatives. The CP3 method consists of five major steps from the identification of common customer needs across product lines to the identification of product modules and platform alternatives. The process makes use of a variety of tools, which will be used to support decision-making, including customer survey, product functional decomposition, customer needs-product specification matrix, product component-performance matrix and the development of a clustering approach for identifying product modules and platform alternatives. CP3 enables multiple views of design constraints and clustering in planning modular product families and platforms. Design teams can use such information to improve existing module and platform architecture or/and to design new concepts. CP3 will provide companies an effective approach to product family and platform planning.

