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Guest Editorial

Special Issue on Computer Aided Conceptual Design (CACD)

Conceptual design is recognized as the most critical stage in design. Yet few CAD tools exist to aid designers in conceptual design tasks, such as clarifying the design requirements and defining its functions, structure, form, interfaces and appearance of products. Often multiple conceptual designs are created and explored, usually in qualitative terms, to determine feasibility of achieving the desired functions and performance specifications. In most cases, schedules and budget do not permit the development and detailed quantitative analysis of all alternatives, so one must narrow down the choices before proceeding to later stages in design. Thus, such evaluation must be carried out with incomplete information. What makes conceptual design different from embodiment and detail design is the creative leap whose roots are in human knowledge, intuition, heuristics, analytic reasoning, expressing, creativity, synthesis and reflections. Computer aided conceptual design (CACD) intends to provide wide algorithmic support to conceptual design, which is fueled by human ideation and creative composition of design concepts. This dependence on human intents, intuitions, cognition, perception, reasoning, preferences, and judgment is what makes computer support challenging. The vagueness or lack of information, the under-determined design constraints, rapid evolution of concepts, multiple aspects of synthesis, and the possibility of alternative solutions introduce uncertainty. In addition, conceptual design is highly domain dependent.

Conventional CAD tools do not provide much support to the designer at the conceptual phase of design. However, one can see from the facts mentioned above that algorithmic formalization of all aspects of conceptual design does not have a strong rational basis and striving for its complete automation does not make sense. Nevertheless, there are some sub-problems in conceptual design that may lend themselves to automation and this is the subject of this special issue. Six full research papers and one technical note were carefully selected from a total of 29 submitted papers, which were peer reviewed and revised in at least two iterations.

Titled *Combinatorial laws for physically meaningful designs*, the first paper by Ramaswamy and Shapiro can be classified as a contribution to computer oriented representation and modeling of design concepts. It proposes an integral representation of geometric and physical information for product conceptualization. In this computational approach, the geometry is represented as oriented cell complex, the properties of which are used in the combinatorial interpretation of physical laws. Further research in this direction might result in a method that is broadly applicable across a wide range of conceptual design problems.

The paper of Zeng, Pardasani, Antunes, Li, Dickinson, Gupta and Baulier, titled *Mathematical foundation for modeling conceptual design sketches,** belongs to the area of mathematical and algorithmic underpinning of computer aided conceptual design. Actually, the intent is to place sketch processing onto a formal basis. It collects the characteristics of hand sketching and the requirements for sketch representation from two experiences. It introduces five axioms to create a formal basis for a sketch representation language, which has been used, in a pilot system for sketch recognition.

In the third paper, titled *Equivalence classes for shape synthesis of moving mechanical parts*, by Ilies and Shapiro, argues that the shape synthesis of mechanical parts can be more efficient and less error prone if it is based on techniques that identify the functional surfaces of the part without imposing arbitrary restrictions of its geometry. They developed a theory based on which the shape can formally be defined for parts moving in contact through equivalence classes of mechanical parts that satisfy a given functionality. The classes of functionally equivalent parts are computable and may be represented unambiguously by maximal elements of each class.

The next paper is related to aggregation and structuring of design information as well as to computer oriented representation and modeling of design concepts. It is titled *"2nd CAD" a tool for the conceptual systems design in electromechanical domain*, by Vargas-Hernandez and Shah, proposes a new informational scheme to represent functions, components, structures and behavior in an integrated way. This paper also makes a contribution to the area of design tools and environments; a CACD tool architecture has been developed, which involves a graphical user interface, a logical programming module, a data management module, and catalog and structure data stores.

Computational issues of a VDIM based multipurpose modeling in conceptual design by Rusak,* belongs to the area of computer support of collaborative conceptual design. It proposes a new approach to modeling of a cluster of shapes in one single representation. The proposed interval model captures the global shape, from which shape instances can be derived by rule based instancing, and by volumetric and physical manipulation. The discrete particle representation facilitates physically based modeling and behavioral simulation of objects in the early phase of design. In addition, the VDIM system facilitates collaborative work and model sharing of dislocated designers. The paper presents the algorithms in action.

A new approach to structure sharing by Chakrabarti and Regno, belongs to the area of both computer oriented modeling and computer enabled optimization of design concepts. Structure sharing is an emerging strategy for conceptual design reasoning. The proposed algorithm starts with combinations of physical principles, fulfilling the requested functions, and creates possible conceptual structures from them. It reduces the iterations needed to develop the concept product and increases the potential for reusing elementary solutions.

*Due to delays in manuscript submission and processing, this paper could not be included in this issue; it will be included in the next issue.

Finally, the Technical Note by Horváth on *Investigation of hand motion language in shape conceptualization*, introduces a novel hand motion language and summarizes the results of the experiments with using this language as an input mechanism for computer aided conceptual shape design systems. The subjects were asked to reconstruct the presented simple, compound and hybrid shapes by sketching them on paper. The fidelity of reconstruction was evaluated together with the efficiency of understanding and regeneration. The results indicate the potential of hand motions in shape conceptualization.

Looking at the advancements reported in these papers, we can see many more deserts than cultivated fields in computer support of conceptual design. Nevertheless, we hope that this compilation of papers gives the reader a preview of the types of CACD tools we might see in use in 5–10 years from now. We thank all authors for contributing to this special issue with valuable papers. We are also indebted to the large number of reviewers for helping us increase the quality of the papers and the value of this special issue.

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