

Research Summary

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1. The CAP Project Design Associate

The Design Associate is intended to be an interactive environment that supports decision-making, performance evaluation, design-record management and knowledge acquisition tasks in computer-aided design. The system is specifically intended to handle the design of complex, physical structures, such as ships and planes, among others. The domain of sailing yacht design is being used as a testbed for developing the design associate. Two key difficulties characterize this type of design problem: (1) Design goals depend on global properties of an artifact. (2) Evaluation of the performance of an artifact is computationally expensive. The Design Associate provides a set of tools for attacking each of these problems: Global constraints are attacked by methods of automatically abstracting and decomposing search spaces. Computational costs of evaluation are attacked by methods of intelligently selecting evaluation models at varying levels of approximation. Future work will extend the Design Associate by building a compiler for automatically generating new performance evaluation models. This extension is intended to support innovative design by diminishing the time and monetary costs of developing new models needed to evaluate radically new designs. Research on the Design Associate is expected to contribute to the field of Computer-Aided Design by formalizing the generic task structure of complex, physical structure design. It is also expected to contribute to the field of Artificial Intelligence, by attacking problems such as search control, search space formulation, abstraction, decomposition, model selection and model formation. (See [Ellman *et al.*, 1992].)

2. Abstraction and Decomposition

One portion of our research is focused on automatic decomposition of design optimization problems. Decomposition is especially important in the design of complex physical shapes such as yacht hulls. Exhaustive optimization is impossible because hull shapes are specified by a large number of parameters. Decomposition diminishes optimization costs by partitioning the shape parameters into non-interacting or weakly-interacting sets. We have developed a combination of empirical and knowledge-based techniques for finding useful decompositions. The knowledge-based method examines a declarative description of the function to be optimized in order to identify parameters that potentially interact with each other. The empirical method runs computational experiments in order to determine which potential interactions actually do occur in practice. We

expect this approach to find decompositions that will result in faster optimization, with a minimal sacrifice in the quality of the resulting design. Implementation and testing of this approach are currently in progress.

3. Model Selection

Another portion of our research is focused on intelligent model selection in design optimization. The model selection problem results from the difficulty of using exact models to analyze the performance of candidate designs. For example, in the domain of racing yacht design, an exact analysis of a yacht's performance would require a computationally expensive solution of the Navier-Stokes equations. Approximate models are therefore needed in order diminish the costs of analyzing and evaluating candidate designs. In many situations, more than one approximate model is available. For example, in the yacht design domain, the induced resistance of a yacht can be predicted by solving La Place's equation - an approximation of Navier-Stokes - or by using a simple algebraic formula. The two approximations differ widely in both the costs of computation and the accuracy of the results. Intelligent model selection techniques are therefore needed to determine which approximation is appropriate during a given phase of the design process.

We have attacked the model selection problem in the context of hillclimbing optimization. We have developed a technique which we call "gradient magnitude model selection". This technique is based on the observation that a highly approximate model will often suffice when climbing a steep slope, because the correct direction of change is easy to determine. On the other hand, a more accurate model will often be required when climbing a gradual incline, because the correct direction of change is harder to determine. Our technique operates by comparing the estimated error of an approximation to the magnitude of the local gradient of the function to be optimized. An approximation is considered acceptable as long as the gradient is large enough, or the error is small enough, so that each proposed hillclimbing step is guaranteed to improve the value of the goal function. Implementation and testing of this approach are currently in progress.

References

- T. Ellman, J. Keane, and M. Schwabacher. The Rutgers cap project design associate. Technical Report CAP-TR-6, Department of Computer Science, Rutgers University, New Brunswick, NJ, 1992.