The Architect's Collaborator: An Intelligent Tool for Conceptual Design

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The Problem: The subject of this research, The Architect's Collaborator (TAC), is a prototype design support system for early stages of the architectural design process. TAC supports iterative design refinement, in particular, representing and reasoning about how architects manifest experiential qualities in physical form. The following scenario illustrates the vision for use of such a tool.

Imagine that you're sketching a design, pen in hand. You tell the computer near you that the design is for a family of four who want a house that feels both spacious and cozy; that invites the community to visit, but protects their privacy. You have ideas about circulation patterns and about physical forms that manifest feelings of privacy, and you're translating those ideas into lines and annotations on a page. You stop to assess your latest sketch and ask the computer for its comments. It graphically shows you access from exterior to interior and within the interior. It shows you regions defined by your proposed physical forms. It tells you that the main living territory is not very private with respect to the exterior. It suggests moving the front door to increase the privacy. It suggests adding a wall or half-wall to create an entry area between the front door and the main living territory. You like the second suggestion and accept it, then continue sketching and consulting with your computer.

Motivation: While some architects may design with only physical form in mind, most create spaces for people to inhabit. They and their clients describe such spaces as private, sunny, open, spacious, etc. Architects use their knowledge—from past experiences, from environment behavior research, from their own theories—to design and build physical form, creating spaces with experiential qualities such as these. This knowledge can be articulated and structured as general design principles, which can serve as a basis for a design support system that reasons about experiential qualities and physical form as in the opening scenario. Few design support systems to date have attempted to represent and reason with this kind of knowledge.

Our View of the Design Process: TAC adopts the view that design is an exploratory search of a design space, trying to turn goals, often unarticulable at the beginning of the process, into physical form that realizes those goals. Because of the complexity of simultaneously satisfying many potentially conflicting goals, it is very difficult to produce feasible solutions in one or a few steps. Instead, a designer engages in an iterative cycle of design refinement: produce a potential solution, evaluate it, modify it, and continue. The designer may modify the design in response to the evaluation, as an attempt to satisfy an unsatisfied goal (a generate-and-test model), or because another goal to be satisfied became apparent (an opportunistic model). TAC assumes that the designer starts with an initial design, e.g. via sketching, then articulates an initial set of design goals, and proceeds with an evaluation and modification cycle.

What TAC Does: To support the designer as in the opening scenario, TAC is organized around the notion of a design problem, which it represents as a design and a set of design goals. Given a design problem, TAC evaluates the design with respect to the design goals, determines which, if any, are unsatisfied, and suggests repairs to the design for any unsatisfied goals. Then for each suggested repair, it creates a new design, and repeats evaluating, suggesting repairs, and creating new designs until it has exhaustively searched for designs that satisfy all the goals. It prunes the design search space by noticing when suggested repairs fail to yield any new designs. The key to TAC's intelligence: when proposing repair suggestions, prior to generating new designs, TAC uses design knowledge—both domain-dependent and general—to search the space of suggestions, pruning conflicting suggestions, consolidating similar suggestions, and ranking the results. Its domain-dependent knowledge includes information about how to manifest experiential qualities in physical form, and how to measure and increase or decrease those qualities. Its general knowledge includes information about how to satisfy unsatisfied goals, how to compare and partially order vector-valued quantities, and how to do simple arithmetic. It also contains an extensive library of computational geometry routines.

Below are screens showing a beginning design, with a living territory visually open from the front porch, and a new design TAC suggested. In the new design, a wall has been added to shield a portion of the living territory from view, thereby decreasing the visual openness of the living territory from the front porch.

file=figures/kkoile-fig1.ps, height=2.6in, width=3.7in

Figure 1: *Design showing portion of Living territory visible from front porch.*

file=figures/kkoile-fig2.ps, height=2.6in, width=3.7in

Figure 2: *New design with added wall; less of Living territory is now visible from front porch.*

TAC's Contributions: TAC provides a framework and a language for representing and reasoning about high level design terms. It translates design goals formulated using these high level terms, experiential terms in TAC's case, into operators on representations of physical form, providing in the process a repository for reusable design knowledge. It provides a scheme for systematically and efficiently exploring the design space in search of solutions satisfying multiple goals. Finally, it serves as an example of distributing design tasks between designer and computer assistant.

The Experiments: Several of Frank Lloyd Wright's Prairie houses were used to explore different aspects of TAC's evaluation, repair suggestion, and new design generation. Several different control structures, goal sets, and goal orders were examined. In addition, six Prairie houses, six non-Prairie houses, and three Frank Lloyd Wright houses considered transitions between pre-Prairie and Prairie periods were the subject of an experiment illustrating the use of TAC to explore characteristics of a building type.

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