Collaborative design system explaining its artifact

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1. Introduction

In design environments, collaboration means more than the division of labor. It contains the notion of cooperation among agents with his or her independent intention.
In a current design system, for example, VEXED (Steinberg, 1987), interactions with its user form a principal part of the design process. The design method which VEXED employed is top-down refinement plus constraint propagation. In this model of design process, the system decides what is possible and the user decides what is wise, that is, the user chooses which piece to refine next, out of all those still needing further refinement, and also chooses which way to refine it, out of all the alternatives that the system knows about that are consistent with the current constraints.
Underlying this type of interactive system is the division of labor taking charge of one part of the homogeneous overall design process.
On the other hand, interactions found between, for example, an architect and its client, are more knowledge-intensive, that is, througn interaction, each gets to know or discovers new things and makes a new decision based on them progressively. Essentially this differs from merely proposing and selecting from among options as in the current interactive design system. Rather, options at a decision point are collected or inferred from new things a client obtained hearing from an architect. For example, consider the simplified process where an client asks an architect to design his cottage.

The process
a) The client describes his requirements using rather vague terms, such as "modern style", "soft touch", or "wide rooms and wide windows". He may refer to several examples in books. And he may also add definite requirements such as "two rooms" and the budget.

b) The architect then recalls some concepts satisfying client's requirements, enriches them with his own idea, and integrates these concepts to produce one ground plan.

c) The architect explains on the ground plan to his client especially about what he thought important, what are additional factors he involved, what he neglected. At first, the client has little idea to decide whether he should accept it, or not. But as hearing architect's explanation, he increases his knowledge enough to form options for his next action and he may ask the architect to change some portion of the plan.

The collaborative design process such as one described above involves many problems to be

solved to mechanize it into the machine. Main problems to tackle for mechanization are as follows.

The design system should produce an artifact from
- incomplete design specifications

The design system should adopt
- designer's own philosophy and intention on designing his or her artifact

The design system should have
- explanation facility on its artifact

The design system should have
- modification facility according to client's instructive requirements

The work reported here is an attempt to embody the design process described above. The attempt, in other words, is to make a knowledge-based design system go beyond a tool for human designer, but to a designer itself for a client.
This paper briefly describes several insights into the model of the design system, its explanation facility, and the characteristics of collaborative interaction based on the explanation facility.

2. Model of the design process

The problem domain we are addressing is Floor Planning. We view the design process as a opportunistic[1] concept activation process. The concept is a strategic prescription and associated to rhetorical goals. Planning proceeds referring to rhetorical goals.
Rhetorics is the term used in Natural Language Field. And rhetorical goals are invented and used in the natural language generator PAULINE (Hovy, 1990). PAULINE produces stylistically appropriate texts from a single story representation under various settings that model pragmatic circumstances. Pragmatic features considered in PAULINE are conversational atmosphere, interlocutor's personal characteristics and speaker's goals with respect to the hearer. But, Hovy argues that most pragmatic aspects do not influence the generator's decision directly, since they are simply too general to be attuned to the requirements of language production. So, he claims that intermediate goals and associated strategies are neended that act as intermediaries between pragmatic aspects and the syntactic decisions the realization components has to make as being sensitive to those goals. These goals are called rhetorical goals.
Natural language generation and floor planning are not the same domain. But still this idea of rhetorical goal is very attractive to formulate the model of the design process, because it is promising as an anchor to capture the various aspects of designer's own intention or strategies to design an artifact under various situations.
So, we assume here that some intermediate description and associated strategies can be identified in a class of design domain including floor planning. We call it also rhetorical goals which exist between, on one hand, initial designer's considerations such as client's requirements, client's life style, the environment of a site and a cost etc., and, on the other hand, a domain theory.

[1] Opportunistic planning is argued in (Hayes-Roth, 1985)

2.1 Planning and realization

In PAULINE, planner performs two types of planning, prescriptive planning and restricive planning. Prescriptive planning acts over and gives shape to long ranges of text. Restrictive planning acts over short ranges of text, usually as a selection from some number of alternatives. Both plannings are performed only when necessiated by the realization process and inquire to rhetorical goals and associated strategies, but not to syntactic information.
Realization in PAULINE is performed by a syntactic specialist to satisfy the syntax goal of the foremost unit in a stream, the central generator data structure, posted by the planner or a preceding specialist.
In floor planning, planning and realization processes will be different from in text generation, because a text is a sequence of words and has no strict limitation to overall size and shape, but a floor is at least two dimensional, and so, elements on a floor are two-dimensionally related to each other and has limited size and shape.
PAULINE's control structure is a stream, a list of units. Each unit is one of three things: a word, a topic goal, or a syntax goal. A syntax goal expands into several syntax goals maintaining a syntax environment.
On the other hand, in floor planning, Design Concept, a network of concepts, is a basic control data structure, and plays a role of blackboard in a blackboard control architecture.
In this scheme, levels of blackboard in a floor planning are what kind of rooms or sections there are, what function each section has, what functional relation each section has to other sections, what topological relation each section has to other sections, where each section is located, and what area and shape each section has. Prescriptive planner exists as a knowledge source corresponding to all levels. Realizer and restrictive planner exist as a knowledge source corresponding to lower levels.
Prescriptive planner in floor planning also refers to rhetorical goals and associated strategies and derives prescriptive concepts from strategies. These derived concepts are placed in an appropriate location in the network of Design Concept.
Symbol analyzer expands concepts in Design Concept into more concrete ones.
Realizer determines primitive elements, i.e., points , edges and parts guided by Design Concept refering to a domain theory.

2.2 Construction of design story as a policy of designing

A designer constructs his own design story as a policy before he begins to determine details, as considering various design conditions with his own philosophy, or intention.
The design story reduces a search space for designing.
In floor planning, the construction of design story is composed of two stages. In the first stage, the system posts rhetorical goals, considering client's requirements, client's life style, the environment of a site, and a cost.
For example, if a client is young and brisk, uses the site only for cooking, eating and relaxing, and the site is narrow, rhetorical goals such as Simplicity, Youthfulness and Novelty will be all posted as High. Strategies associated to the rhetorical goals are as follows.

- when Simplicity is high, if site is narrow, limit the number of sections as few as possible.
- when Youthfulness is high, if kitchen is involved, locate kitchen at light place.

- when Youthfulness is high, if living room is involved, make living room as wide as possible.
- when Novelty is high, if living room is involved, give variation to living room.

In the second stage, prescriptive planner corresponding to each level of blackboard is activated opportunistically, and places concepts derived from strategies into Design Concept. When prescriptive planning in the second stage is over, initial Design Concept as a design story will be as follows.

- Living-Room; shape:Variation ;
  from RG:Novelty
  width: Wide ;
  from RG:Youthfulness
  position: South;
  from general strategy
- Kitchen; position: LightPlace ;
  from RG:Youthfulness

2.3 Explanation facility

The design system can explain on its artifact refering to Design Concept. The purpose of explanation is to let its client know overall design rationale, help him or her to decide whether to change or not the artifact, and in the case of changing, capture the right way to change it.
First, the design system explains about overall design rationale based on the design story which it constructed before starting to design details.
In Explainable Expert Systems framework[EES] and its prototype expert system, the Program Enhancement Advisor[PEA](Nechs et al., 1985), an extensive development history is created that records the goal structure and design decisions behind the expert system. This structure is available for use by the explanation facility, but reflects only goal refinement process.
The design process discussed above mainly comprises opportunistic concept activations, so more dynamic structure, i.e. Design Concept is necessary to record design rationale.
Various types of explanation needs to follow that, responding to various types of question including "what if" or "why"(Moore et al., 1989).
Topics of explanation is collected from concepts posted in Design Concept. So, Design Concept serves as a topics reservoir. For explanation of design story, topics collection and organization are determined heuristically in the order of hieararchical levels of Design Concept as a blackboard. The main issue for responding to questions is focus control. Focus control mechanism needs to cooperate with user interface feature.

3. The characteristics of collaborative interaction in floor planning

If in the proposed floor plan, a kitchen is located at the corner of south-east, and a living room has the shape of character L, the design system will explain about this floor plan as follows.

I limit the kind of rooms to a living room and a kitchin to make the configuration simple and the living room wide.
I give shape of L to the living room to produce novelty.

I locate the kitchen at the south-east corner to produce youthfulness by making it light.

After hearing this explanation, the client gets to know designer's basic intention. And often, this intention is amazement and new idea for him.
Explanation of design story also informs client of accompanying design conditions, if any, besides design rationale.
For example, at first before hearing design story, the client feels unsatisfactory to the location of the kitchen. And after hearing it, in one case, he may agree to designer's intention. But in another case, he remains still not satisfied and he tries to know whether changing it is appropriate or not. And if there can be found no additional conditions which justify the proposed plan, and the explicit condition which prevents to move the kitchen to his favorite location, he will decide to change kitchen's location to, for example, the south-west corner.

If the client wants to change the proposed artifact, he will ask the design system to change it as he instructs through user interface feature. If so, the design system first modifies the appropriate portion of Design Concept , and restarts planning and realization. This redo is different from chronological backtracking.
The collaboration in this design system is characterized by two main facilities. One is the explanation facility to help a client to capture the most appropriate change to satisfy and convince himself and to instruct it to the design system. The other is the redo facility to change the artifact according to client's instruction.

4. Conclusion

We have partly hypothesized several principles for the model of collaborative design system. But much remains to be resolved to formulate principles on the blackboard control architecture of planning and realization, explanation facility, and redo mechanism.
The work to be done next is to implement a prototype system realizing the model.
We started this work for the purpose of developing a design system for entertainment for consumer market. But some principles developed in this work will be applicable to other fields of design.

5. References

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