# Computers as Design Collaborators: Interacting with Mixed - Initiative Tools

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## Abstract
Techniques in procedural content generation and computational creativity enable AI systems that can assist with the creation of content in design support tools. These AI systems are capable of acting as design collaborators, suggesting variations on content and offering expertise to the tool user. However, there is a large difference in the way humans are expected to interact with these tools versus interacting with other human design collaborators. This paper discusses the role of creative computers in design support tools and how it differs from that of their human counterparts, and details three issues in the development of mixed-initiative design support tools.

## Keywords
Mixed-initiative tools, computational creativity, procedural content generation, design support tools.

## ACM Classification Keywords
D.2.2 Design Tools and Techniques.

## General Terms
Design, Human Factors.

## Humans and Computers Collaborating

Creativity and design support tools increasingly involve computers directly in the design process, with the computer responsible for creating content and contributing to the final product, guided by the human designer. Such systems often take a mixed-initiative approach, with the human and computer entering a design conversation where each contributes ideas to the final design. The AI systems incorporated into these tools are frequently capable of creating similar content autonomously, simulating the role of the human designer. The human is generally responsible for adding constraints to the design space the computer operates within, such as specifying a building size or river location in a virtual world development tool [6].

The role of the computer in such systems is described by Lubart as that of a "colleague" [2]. However, the ways that humans interact with these systems reveals that the colleague is generally not considered an equal partner in the design process. The computer typically plays a subordinate role, obeying the instructions of the human designer, producing content to meet her goals, and never questioning her decisions unless there are logical contradictions. While this is undoubtedly a useful role for the computer to play, it is quite different from that of a human colleague.

Collaborative design between humans tends to be more a partnership of equals. For example, consider a scenario where two participants, one an engineer and the other an artist, work together to design a video game. While each participant brings different skills to the table, they work together by brainstorming different ideas, asserting their expertise when appropriate, defining their own constraints, and negotiating towards a mutual goal. Furthermore, conversation between two designers is not strictly turn-based, unlike mixed-initiative systems where turn taking is the norm; the artist may interrupt the engineer to request clarifications, to correct assumptions or to suggest a new idea, or the two designers may work in parallel to create separate prototypes before combining their ideas.

This kind of collaboration is essential in interdisciplinary fields, where there are several experts from different areas negotiating complex interdependent aspects of the project. There is great potential for the adoption of design support tools for novices in these fields, with the computer acting as a domain expert outside of the user's area of knowledge. However, existing approaches to mixed-initiative design do not support this form of collaborative design with a computer.

## Engaging Computers as Creative Equals

In his paper describing the four different roles a computer can take in a creativity support tool, Lubart describes the "most ambitious" role as that of a colleague [2]. This role involves a human and computer working closely together to create content, taking turns modifying an artifact until the human declares it done. There are many systems that currently fulfill this role [3][5][6], including our own work on Tanagra [7], a mixed-initiative design tool for 2D platformer levels. However, the role that the computer plays in these systems is generally that of a subordinate to the human designer. While the computer may be performing tasks that the human is unable to do themselves, it is always in the service of a human-stated goal.

We suggest a refinement of this "colleague" role: the "computer as collaborator". In this capacity, the computer is elevated to equality with the human designer and is able to more strongly influence design decisions based on its expertise. We see three central issues in the creation of future "computer as collaborator" systems, issues that touch on both AI system design and user interface concerns. At the core of all of these issues is the need to imbue the AI system with an ability to argue about design: the system should understand and explain its reasons for any actions it takes, be capable of engaging in a debate with the human about design, and compromise on design decisions.

*Negotiating High-Level Design Goals*

The collaborative design process is characterized by the negotiation of high-level design goals. Two participants may have drastically different ideas about the final product, be aware of different constraints, and have different approaches to solving problems. While these differences can offer some challenges, a diversity of opinions can also lead to more productive design conversations and a more interesting final product.

Current mixed-initiative systems have the human set all of the goals for the project, whether explicitly or implicitly, and the computer acts in fulfillment of these goals. Negroponte warns that computers in creative support roles should not push their own agenda on the human [4], instead allowing the human to make all of the major design decisions and use the computer to amplify their own design potential. We agree that the computer should not dominate the design conversation; however, its expertise must be reflected when negotiating design goals, and both the suggestions it makes and the constraints it provides can lead to more productive design discussions.

*Overriding Human Decisions*

Current systems hold human decisions paramount over all other considerations in the system. For example, Songsmith's harmony generator [5] will never change the melody that has been written by the human, but can accommodate changes to the melody that are made later during composition. Human collaborators, in contrast, will frequently request that certain prior decisions be overridden in favor of new ideas. A game designer might suggest that a mechanic that was previously considered important be removed from the game to accommodate a change made to the game's story, for example. These changes are, ideally, done politely and with the cooperation of others on the design team.

An AI system that will collaborate as an equal with a human designer must therefore be able to override decisions made by the human as appropriate, and vice versa. This requires the AI system to record when decisions are made and the context in which they are made, so that it can infer which decisions are likely to be reversible and which are not. It also requires the AI system to be able to explain the decisions it is making in the context of larger design goals, so that the human understands what its collaborator is doing and why.

*Moving Away from Turn-Taking*

In order to support both design goal negotiation and decision overriding, the interface of a collaborative mixed-initiative system must support the computer interrupting the human designer. Current mixed-initiative systems are generally reactive, with a turn-

taking "conversation" occurring between human and computer participants. However, conversation between human designers rarely follows a strict turn-taking model; there are frequent interruptions when both parties have something to say on the topic at hand, and pauses when both parties must think about how to address a particular problem. Furthermore, neither participant is purely reactive to the other, as current mixed-initiative systems tend to be. Instead, each designer takes a proactive role in contributing to the final product.

To accommodate these changes, mixed-initiative interfaces must be modified to move away from the turn-taking model of interaction towards a more sophisticated design conversation. Two of Horvitz's design principles for mixed-initiative systems are "employing dialog to resolve key uncertainties" and "employing socially appropriate behaviors for agent-user interaction" [1]. These two principles are key in the move away from a turn-taking conversation; the computer must be able to politely interrupt the user with its own suggestions without annoying the user through needless dialogs.

The three issues presented here are central in the development of both new AI systems to support collaboration, and the interfaces that allow a user to interact with a proactive, creative computer. There is a great deal of research to be done towards this goal, both in building creative systems that can explain their design decisions, understand decisions made by humans, and operate in parallel to a human designer, and in designing appropriate user interfaces for a computer as a creative equal.

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