Human - Machine - Design Matrix

A Mode/for Web-based Design Interaction

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A model of human-machine design interaction is presented. The model is based on synchrony of actions [Mitchell95a] as it relates to designing, presenting, and discussing a design object over an electronic medium. The model descriptively accommodates existing technologies and areas of CAD research. The model prescriptively illuminates future CAD vis. the Web. The model is based on 3 factors : synchrony, presence, activity; and 2 players : human and machine. Future technologies are considered in terms of the a shifting role of the machine (the computer and the net) from server to agent to actor.

1. Starting Point Synchrony and Presence

In The City of Bits, Mitchell identifies and contrasts common forms of person to person communication in terms of physical versus virtual presence, crossed with synchronous versus asynchronous actions. The emerging world of the Web is at the center of a heated transformation from physical to virtual. Electronically mediated counterparts to conventional physical forms of communication are taken to a new extreme when considered in the context of the World Wide Web (the Web).

	Physical	*Virtual*
Synchronous	[1] Physical Presence, Synchronous (*Face-to-face meeting*)	[3] Virtual Presence, Synchronous (*telephone, video conference, electronic meeting, talk radio*)
Asynchronous	[2] Physical Presence, Asynchronous (*Leaving messages, mail*)	[4] Virtual Presence, Asynchronous (*email, fax, electronic bulletin board*)

Figure 1: Matrix-1 - The starting point from [Mitchel/195a].

2. Design Extensions

The application of virtual presence, synchronous and asynchronous actions have been put into practice. Virtual design studios [Mitchel/95b] [Wojtowicz95] have shown how existing technologies can be applied to design studios that are spatially and temporally disjunct. Email, Web pages, remote file transfers, video conferencing, whiteboards [B1y88] and other existing communication technologies have been used to show how collaborative designing can be extended via the internet.

This paper extends the idea of synchrony and presence, first as a descriptive framework for design activities and second as a prescriptive model of how the machine (i.e. networked computational machines) can play a greater role in design activities vis. the Web.

Synchrony and presence has been related specifically to architectural design in "Aspects of Asynchronous and Distributed Design Collaboration" by Wojtowicz, Papazian, Fargas, Cheng and Davidson in [Wojtowicz95], switching 'local' and 'global' for 'physical' and 'virtual':

	Physical	*Virtual*
Synchronous	[1] (*Face-to-face meeting*) Conventional design studio	[3] Design teleconference, videoconference
Asynchronous	[2] Digital design correspondence, pinup board	[4] Networked design studio

Figure 2: Design collaboration matrix - [Wojtowicz95].

The above description includes general design related activities. It may be useful to further articulate distinct (if not iterative) acts within the design process. The purpose of this subdivision is to identify distinct differences and implications for where machine role and human purposes can be advanced.

Presuppose that designing is subdivided into acts of creation, presentation, and discussion of a design component (i.e. the representational object - the artifact). The initial four quadrants of Matrix- 1 expand into 3 sets of 4:

2.1. DESIGNING THE COMPONENT.
The term designing is used here as an act of creating or modifying a representation of an (architectural) object with the aid of tools. Matrix-1 simply translates to:

A. Designing	*Physical*	*Virtual*
Synchronous	**[1A]** Physical Presence, Synchronous *designing*	**[3A]** Virtual Presence, Synchronous *designing*
Asynchronous	**[2A]** Physical Presence, Asynchronous *designing*	**[4A]** Virtual Presence, Asynchronous *designing*

Figure 3: Design Matrix

[1A] Physical presence, synchronous designing occurs when a design team works within the same physical space. This is the traditional studio situation.

[2A] Physical presence, asynchronous designing occurs when drawings, models, notes and other physical media are worked on and exchanged between designers without direct contact. This is also part of the traditional design studio situation when designers have different schedules.

[3A] Virtual presence, synchronous designing occurs when the computer is used as an interactive tool by more than one designer. At the low end of the complexity spectrum, is the electronic white-board, where designers can draw on a common electronic document. At a higher level of complexity, designers could be working on a 31) model simultaneously in real-time. Ultimately, this becomes real time multi-user CAD.

[4A] Virtual presence, asynchronous designing occurs when the computer is used by a group of designers that do not see each other's changes instantaneously and are not constrained by other's actions. If a design starts from a common state, then proceeds asynchronously, multiple versions are produced. If such versions are brought together, then discrete actions, i.e. changes, are serialized and made into a unified model. This is serialized or multi-version CAD [Katz86] [Kim97].

A. Designing'	*Physical*	*Virtual*
Synchronous	**[1A]** Conventional Team Designing	**[3A]** Multi User CAD
Asynchronous	**[2A]** Design Exchange	**[4A]** Multi Version Multi User CAD

Figure 4: Design Matrix re-codified

2.2 PRESENTING THE DESIGN COMPONENT

Presentation is defined here as fundamentally uni-directional. A story is told, and objects are presented without viewer interaction with the presenter. Unlike the prior case where the focus is on creating or modifying a design object, the purpose here is to communicate the design object - in whatever state it is in.

B.Presentation	*Physical*	*Virtual*
Synchronous	**[1B]** Physical Presence, Synchronous *presentation*	**[3B]** Virtual Presence, Synchronous *presentation*
Asynchronous	**[2B]** Physical Presence, Asynchronous *presentation*	**[4B]** Virtual Presence, Asynchronous *presentation*

Figure 5: Presentation Matrix

[1B] Physical presence, synchronous presentation occurs during the course of conventional presentations in front of an audience. This is the conventional presentation or lecture.

[2B} Physical presence, asynchronous presentation occurs when a designer leaves a physical model or a drawing for someone to review. An exhibit is a more public example. In all cases, the design object stands by itself without its designer to present it in person.

[3B] Virtual presence, synchronous presentation occurs during a guided tour through a design by the designer, via tele-presence. This case includes live broadcasting I live viewing and one way video link.

[4B] Virtual presence, asynchronous presentation occurs when a design object is put on virtual display. As with case [2B], the design object has to stand by itself -- as a drawing, a HTML page published onto the World Wide Web [HTMLa] [HTMLb][HTTP], a virtual reality model [Ames96], an animation, or a video taped presentation. This can be extended to include a virtual museum and virtual places (such as VRML worlds).

B.Presentation'	*Physical*	*Virtual*
Synchronous	**[1B]** Lecture/Presentation	**[3B]** Tele-Presentation
Asynchronous	**[2B]** Physical Exhibit	**[4B]** Electronic Publishing, Virtual Museums, Virtual Worlds

Figure 6: Presentation Matrix re-codified

2.3 DISCUSSING THE DESIGN COMPONENT

Discussion is the bi-directional extension to presentation. A means of response, and a sense of participatory equality is necessary in this scenario. Once again, it is distinct from designing because although they are both bi-directional, the purpose in the discussion is to communicate and inquire about the design (object). Although comments may lead to altering the design object, its immediate purpose is discourse.

C. Discussion	*Physical*	*Virtual*
Synchronous	**[1C]** Physical Presence, Synchronous *discussion*	**[3C]** Virtual Presence, Synchronous *discussion*
Asynchronous	**[2C]** Physical Presence, Asynchronous *discussion*	**[4C]** Virtual Presence, Asynchronous *discussion*

Figure 7: Discussion Matrix

[1C] Physical presence, synchronous discussion is the conventional design review or critique.
[2C] Physical presence, asynchronous discussion occurs when drawings, models, data are passed back and forth and returned with comments. This is a physical form of 'Request for Comment'.
[3C] Virtual presence, synchronous discussion is a tele-review with shared media. Video conferencing, internet audio, white boards are the technologies that can be applied to this area.
[4C] Virtual presence, asynchronous discussion is the 'Request for Comment'. An exchange of email on a design is a simple example. A discussion group on an electronic form is another example. This case can also be embodied in Web site that allows comments to be made with a running commentary complete with images and models.

C. Discussion'	*Physical*	*Virtual*
Synchronous	**[1C]** Meeting / Critique	**[3C]** Tele-Critique
Asynchronous	**[2C]** Physical requests for comment	**[4C]** E-forum

Figure 8: Discussion Matrix C Re-codified

2.4 SUMMARY

Summary *A-Designing* *B-Presenting* *C-Discussing*	*Physical*	*Virtual*
Synchronous	**[1A]** Team Designing **[1B]** Lecture/Presentation **[1C]** Meeting / Critique	**[3A]** Multi-User CAD **[3B]** Tele-Presentation **[3C]** Tele-Critique
Asynchronous	**[2A]** Design Exchange **[2B]** Physical Exhibit **[2C]** Physical RFC	**[4A]** Multi-Version Multi-User CAD **[4B]** Electronic Publishing, Virtual Museums, Virtual Worlds **[4C]** E-forum

Figure 9: Summary

3. Web/Machine Roles

The areas distinguished by the model so far do not specify how a globally networked computing system (i.e. the Web) is significant. This can be approached by considering the role of the machine (i.e. the networked computational system). The role of the machine can be described in 4 discrete role-levels, ordered in increasing machine involvement:

(1)The machine as a communication medium between persons (medium); (2)The machine as a processor and store of information (server); (3)The machine as that acts on the behalf of a person (agent) [Kay84] [Maes84] [Maes93] and ultimately, (4)The machine as an intelligent, autonomous cohort (actor).'

The computer aided design implications for treating the computer within these capacities are now evaluated in relation to the multi-dimensional matrix developed so far.

Synchrony	x	Presence	x	Activity	<=>	MachineRole
				design		medium
synchronous		physical		presentation		server
asynchronous		virtual		discussion		agent
						actor
Starting matrix (4)						
Design Extensions (12)						
Machine Roles (48)						

Figure 10: Synchrony, Presence, Activity and Machine roles

Up to this point, there has been an implicit assumption that the parties participating in the articulated activities {designing, presenting, discussing} are human - i.e. the roleplayers are human, and the tools are physical (pen, paper, wood, saws...) or electronic (computer, telephone, fax).

An abstract (producer-consumer) data flow model [Pressman87] [Yordon78] [DeMarco79] will now be used to articulate a more precise relationship between players, and in particular, identify roles that both human and machine do and can play.

Starting with a simple a model of information flow between 2 entities. One entity is the producer of information. The other entity is the consumer of information. This is a unidirectional model of information flow.

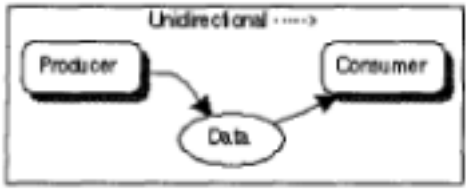

Figure 11: Producer and consumer of information.

If both entities are information producers and consumers, then a bi-directional elaboration follows

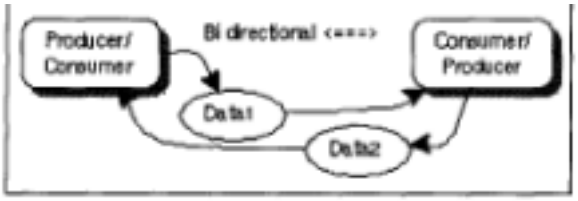

Figure 12. Bi-directional information flow.

So far, the model is abstract and does not specify by what means the information passes between the two parties. This is the point where the role of the machine needs to be defined. The omission of the machine as an intermediary reduces to scenarios of traditional physical person-to-person interaction. Given that the focus is the involvement of the machine (networked computational machine), only cases involving the machine will now be explored.

3.1 MACHINE AS COMMUNICATION MEDIUM

The simplest use of the machine is as a communication medium between parties. This is a storage-less (secondary, not primary or cached) use of the machine, exemplified in the telephone, the video teleconferencing devices, and fax machines.

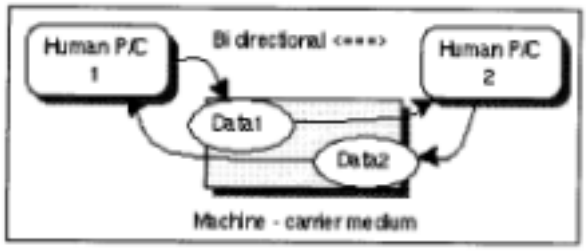

Figure 13: The machine's role is as carrier medium of information.

In relation to the activities of designing, presenting and discussing designs, the machine as communication medium is exemplified by design whiteboards, presentation broadcasting, discussion tele-conferencing. Only synchronous activities are possible without the use of secondary storage. These activities occupy the synchronous-virtual quadrant of the matrix.

3.2 MACHINE AS INFORMATION PROCESSOR/SERVER.

The introduction of (secondary) storage into the machine allows for storage of information. Information produced does not have to flow directly to consumers. It can be stored in the system , processed and served to consumers on demand

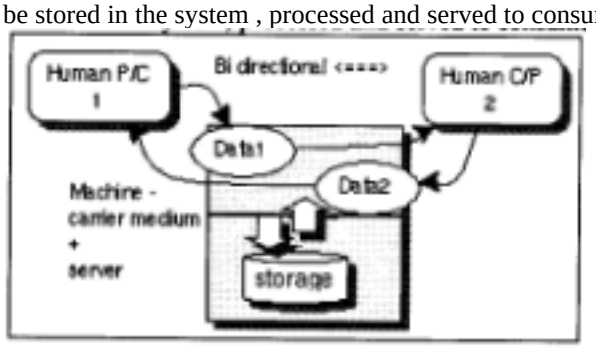

Figure 14: The machine's role is expanded to storage and basic processing of information.

The role of the machine as information processor and server is well known today. All computational machines have some form of primary and secondary memory, and therefore have the capacity to store and process information. What is really of interest in using this incredibly simple model, is how it relates to the prior model of synchrony and presence.

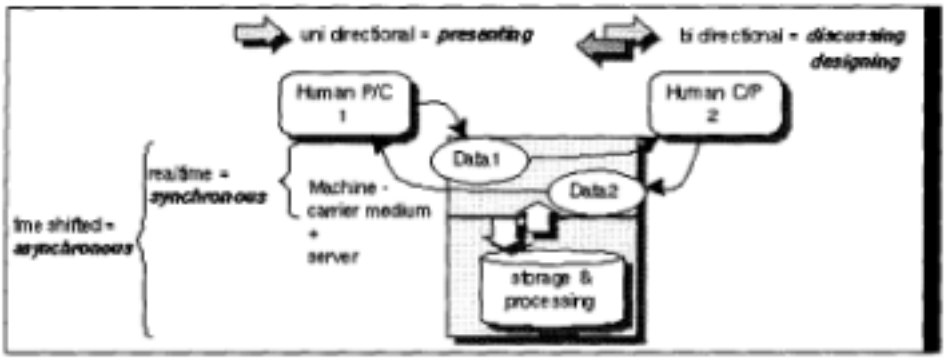

Figure 15: Information flow and machine role are mapped to synchronicity and activity.

Synchronous activities in principle do not require secondary storage - these are real time activities. Asynchronous activities, however, require secondary storage - these are time shifted activities. For example, real time streaming of digital audio over the internet [Audio] can be done via peer-to-peer connection between the talker (the audio producer) and the listener (the audio consumer). In contrast, communicating between 2 (or more) parties by posting information on a Web site or a electronic bulletin board is an asynchronous (time-shifted) activity. The producer of information (the Web author) relies upon the machine's storage system to store and serve the information to consumers (readers/surfers).

The direction(s) in which information flows helps to distinguish in machine terms, what designing, presenting, and discussing requires (not what they are). Presenting is in essence a uni-directional activity. The lecture, the video taped or animated movie presentation, and the broadcasting show are all not interactive - information flows from the presenter (the information producer) to the audience (the information consumers). In contrast, interaction requires bi-directional flow of information. Collaborative designing, and discussion of a design requires a feedback loop [Bly88]. In the first case, the design object is being created collaboratively, and in the second, it is being exhibited and discussed.

3.3 MACHINE AS (DESIGN/PRESENT/DISCUSS) AGENT

Up to this point, the machine's role is first as a carrier of information, and then as storage vessel, conventional processor and server of information. The players have always been the human designers. The next step is to consider the networked computational machine as an agent - specifically as a design-agent, presentation-agent, and discussion-agent, within the context of synchrony and collaboration.

Agents are software programs that act on specific tasks on the behalf of others, with a degree of autonomy [Maes84]. Intelligent agents may employ reasoning or knowledgebased technologies. Intelligent autonomous agents is a intense area of research, including in computer aided architectural design - e.g. intelligent navigation and presentation agents [Engeli95}, sans Web enablement.

Presently, agents are considered in terms of synchrony and collaboration. The following are proposed articulations of the machine-as-collaborative-agent. They directly derive from the outlined codification and from the open prospective availability of human and machine resources on the Web..

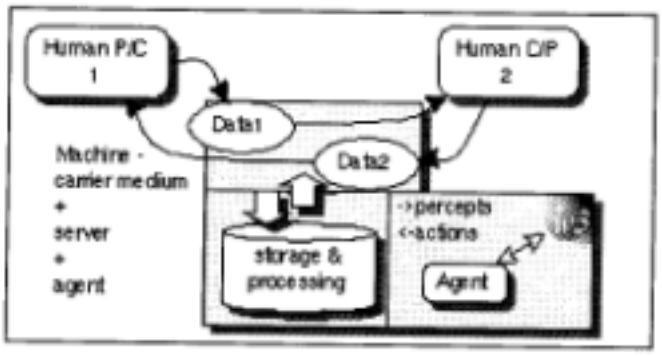

Figure 16: Information Agents add a further level of processing capability to the machine's role.

3.3.1 *Proposed Web /Machine Roles - Synchronous Collaboration Agents*
Agents can engage designers/presenters/discussants on synchronous media (e.g. video conference, whiteboards, etc.) on demand. The collaboration agent is synchronous because the participants are connected by synchronous (real-time) media. For example, if a critic is needed to discuss a design, a collaboration agent could search for an available candidate and hook that person up. If someone was needed to help design a component, the collaboration agent could find an available designer to hook up to the other side of a whiteboard or CAD system.

Area	Possible Uses
Synchronous-design-agents :	-- agents that connect up designers via video-conference based on needs or requests. -- agents that generate design alternatives on the fly, as the design collaboration takes place -- agents that add information to the design as it is developing (without constraining it)
Synchronous-presentation-agents :	agents that find an audience to hear a presentation or to find a speaker on a topic.

Synchronous-discussion-agents :	agents that find critics to discuss a design.

Figure 17: Possible use of synchronous agents.

3.3.2 *Proposed Web /Machine Roles - Asynchronous Collaboration Agents*
Asynchronous collaboration agents can be differentiated from synchronous counterparts by capitalizing on time-shifted availability and independence of Web resources and participants. Agents can act to match asynchronous requests for and submissions of information between parties. This scenario is the electronic design marketplace, where the design agent finds a suitable match to your request for a component or tool. The marketplace is asynchronous because the market participants (designers, presenters, critics) contribute or make requests at different times, autonomously from other parties. It then becomes the agent's task to 'make the market' , or broker exchanges, by searching, analyzing and matching producers and consumers of (design) information. The response from the agent may be real-time or time-shifted.

Area	Possible Uses
Asynchronous-design-agents :	-- agents that manage a marketplace for design components and tools. -- agents that attempt to reconcile and put together designs as they develop
Asynchronous-presentation-agents :	-- agents that create a marketplace for pre-recorded presentations and audiences. -- Presentation agents can also be used to guide the audience through the material in a custom fashion
Asynchronous-discussion-agents :	-- Agents that match people to discussions in an electronic forum. -- Agents that comb through designs and present critiques and commentary from a specific viewpoint (perception rules).

Figure 18: Possible use of asynchronous agents.

One can imagine, that the advent of a collaborative design environment with designing/presenting/discussing agents, would upon submission of a design object or online creation of a design object, get responses back from both human collaborators and agents. Given that human participants and agents could be selective (private, by invitation only), or public (as much of the Web is still), design feedback, spontaneity and serendipity could flourish.

Fantasy design log :

- creating my design online...
- a materials agent encounters my design and gives me a suggestion to some interesting textures encountered at http://...
- I go away for java...
- I check the project web site and my design has been rendered and integrated into the master VRML model...not bad but what until the crit-agents get a handle it!
- working late...and I get blasted into this a video conference on nurbs, gotta go!
- end log 97.04.14:02:02

Figure 19: Fantasy design log in the era of design agents.

3.4 MACHINE AS (DESIGN, PRESENTATION, DISCUSSION) ACTOR

Agents act on the behalf of another. Actors are first class participants. Whereas agents are asked to perform a defined task for a design participant, such as finding a design component, an actor is a collaborator - a designer, a critic, an intelligent guide. The role of the machine then becomes that of participant - collaborator. In the producer/consumer model, the machine assumes the (formerly solely human) role. This ultimate scenario is the design example of a Turing test [Turing5O], where design collaborators over the Web do not know whether the design collaborator, the presenter or the audience, or the design critic is a person or a machine.

As agent technologies develop and diversify into a myriad of embedded specializations it is plausible to extrapolate - perhaps in the conceptual flavor of Minky's Society of Mind [Minky85] - to the level of intelligent electronic actors.

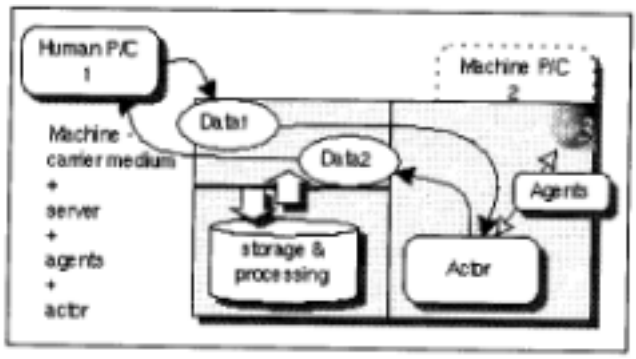

Figure 20: The machine as Actor becomes a first class participant.

4. Concluding Remarks

The advent of the Web does not change or alleviate many design computation problems. It sets a globally shared virtual environment in which to test and solve problems. The Web is an electronic playground where participants across the ether can be known or unknown, singular or countless, man or machine. Actions and requests for information can occur in synchrony or asynchrony with collaborators. When the networked computational machine's role is expanded beyond that of carrier medium or processing engine, or information server, to that of agent and ultimately of participant, new possibilities for design collaboration appear.

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[HTMLa] http:/!www.ncsa.uiuc.edu/General/Internet/WWW/HTMLPrimer.html

[HTMLb] http:!/www.w3.org!pub/WWW/MarkUp/

[HTTP] http://www.w3.org/pub/WWW/Protocols/

[1] The actor-agent-server paradigm is used by [Booch94] to differentiate software objects by their complexity : an actor is an object that can operate on other objects but is never operated upon by other objects; an agent can both

operate upon other objects and be operated upon by other objects. An agent acts on the behave of an actor or an agent; a server never operates upon other objects by is only operated upon by other objects. A server provides services. This is congruent with more general uses of the terms. Servers provide a formal set of set-vices (communications, database management, repository services, global naming services, etc.) [Simon95]. An agent is generally described as something that perceives and acts in an environment [Russell95]. Agents contain knowledge, can work autonomously, work on specific tasks on the behalf of others.