Socio-Technical Environments in Support of Learning, Participation, Collaboration, and Design

The Envisionment and Discovery Collaboratory (EDC)

Hal Eden and Gerhard Fischer
Center for Lifelong Learning and Design (L3D)
CU Boulder

Acknowledgments. The Envisionment and Discovery Collaboratory (EDC) is a long-term research effort with the contributions of many researchers in L3D. Special thanks go to:

- **Ernesto Arias**, whose work and ideas inspired the whole effort and who envisioned and initiated numerous major developments; and
- **Eric Scharff**, who in the context of his PhD research, developed essential parts of the first prototypes of the EDC.

Objectives

In the past decades, the primary goal of most collaborative systems has been to achieve better productivity in various domains by supporting well-established processes and actions. Today’s society is characterized by increased professional specialization, constant changes in the marketplace, and rapidly emerging technologies for information and communication. The knowledge required for framing and solving complex problems is not simply the sum of each participant’s knowledge, but the result of a process of knowledge exchange and construction embedded in social interaction, which we refer to as social creativity.

The primary question underlying our research is:

> *how can we create and effectively support reflective communities engaged in the design of a leading-edge community-oriented development.*

This primary question then leads to the more specific concerns:

- how can stakeholder communities who are impacted by the activity (and not only experts) collaborate to design solutions to real problems;
- how can multiple perspectives related to the design process (including expertise from a broad variety of domains, governmental and community needs, client needs, etc) be articulated, represented and effectively utilized;
- how can the presentation and access to data and information be improved for all participants; and
- how can participants’ tacit and implicit understanding of issues be drawn out.

The Envisionment and Discovery Collaboratory (EDC)

The Envisionment and Discovery Collaboratory (EDC) is a long-term research platform that explores conceptual frameworks for social creativity and democratizes design in the context of framing and resolving complex urban planning and emergency management problems. The knowledge to understand, frame, and solve these problems does not already exist, but is constructed and evolves in ongoing interactions and collaborations—an ideal environment to study social creativity and collaborative design.

At the technological level, the EDC integrates tabletop computing environments, sketching support, GIS systems, Google Earth, visualization software, and an envisioned virtual implementation.

The EDC supports problem-solving activities by bringing individuals who share a common problem together in face-to-face meetings and promoting a form of social reflection-in-action. A problem is discussed and explored by providing participants with a shared construction space in which they interact with computationally enhanced physical objects that are used to represent the situation (action space). Computer-generated information is projected back onto the tabletop construction area, creating an augmented reality environment. This construction in the tabletop environment is coupled with
information displayed on a vertical electronic whiteboard relevant to the problem currently being discussed (reflection space). A key unique aspect of the EDC is that the emphasis has been on the collaborative construction of artifacts rather than the sharing of individually constructed items.

The Envisionment and Discovery Collaboratory (EDC) is a socio-technical environment that the research team has been developing to support reflective communities. Appendix 3 shows a report in the Engineering College’s Alumni Focus publication that describes the EDC being used in a meeting between the City of Boulder representatives and CU leadership at the L3D laboratory to discuss perspectives and explore computational models related to a design problem of common interest and concern.

The EDC provides participants with a shared construction space (the PitA-Board) in which to interact with computationally enhanced physical objects and use them to represent the situation currently being discussed. The proposed research will extend the social and technical infrastructures of the current EDC to reinforce both physical and computational mediation to enrich communication and interactions between participants.

The complex design problems that we are exploring with the EDC do not have one optimal solution; the various solutions depend on the participation of the different people having stakes in the problem. Solving problems in the EDC requires a reflective community, and the technical and social features of the EDC are designed to enhance the reflective and creative practice of such a community.

Crucial processes relevant for collaborative design and lifelong learning that are supported by the EDC:

- dealing with a set of possible worlds effectively (i.e., exploring design alternatives) to account for the design is an argumentative process, where we do not prove a point but we create an environment for a design dialog;
- using the symmetry of ignorance (i.e., that all involved stakeholders can contribute actively) as a source of power for mutual learning by providing all stakeholders with means to express their ideas and their concerns;
- incorporating an emerging design in a set of external memory structures, and recording the design process and the design rationale;
- creating low-cost modifiable models, which help us to create shared understanding, have a conversation with the materials, and replace anticipation (of the consequences of our assumptions) by analysis;
- using the domain orientation to bring tasks to the forefront and support human problem-domain communication;
- increasing the “back-talk” of the artifacts with critics; and
- using simulations to engage in “what-if” games.

The EDC has been applied in numerous real world projects (in collaboration with the City of Boulder and the University of Colorado) including:

- Urban planning problems (e.g.: the development of the East Campus of CU);
- Human-centered transportation systems and transit-oriented developments (e.g.: the FasTracks project in the Denver Metro Area); and
- Emergency management (e.g.: emergency management education and training for preparedness with City of Boulder and CU Boulder).

Remark: More information about the EDC, the theoretical framework behind it, and the application environments for which it was used can be found in numerous publications (with PDF files for downloads): http://l3d.cs.colorado.edu/~gerhard/papers.html

This document illustrates the EDC and discusses some of its features with three appendices:

- Appendix 1: An Illustration of the EDC
- Appendix 2: Brief Description of Technical Aspects of the EDC/PitA-Board
- Appendix 3: Article in CU’s Engineering College’s Alumni Focus
Appendix 1 provides brief descriptions and illustrations for the following themes:

<table>
<thead>
<tr>
<th>Theme</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of Action and Reflection Spaces</td>
<td>4</td>
</tr>
<tr>
<td>Sketching</td>
<td>5</td>
</tr>
<tr>
<td>Land Use Scenario</td>
<td>6</td>
</tr>
<tr>
<td>Emerging Insight: Illustrating Multiple Walking Distances</td>
<td>7</td>
</tr>
<tr>
<td>Boulder City Council and University of Colorado Regents</td>
<td>8</td>
</tr>
<tr>
<td>Application Context — Emergency Management: Wildfires</td>
<td>9</td>
</tr>
<tr>
<td>Application Context — Emergency Management: Flooding</td>
<td>10</td>
</tr>
<tr>
<td>Caretta: Integrating Individual and Social Creativity</td>
<td>11</td>
</tr>
<tr>
<td>3D Visualization</td>
<td>12</td>
</tr>
<tr>
<td>Extending Participation with the EDC_{VR}</td>
<td>13</td>
</tr>
</tbody>
</table>
Appendix 1: Illustrations of the EDC

Integration of Action and Reflection Spaces

The Figure 1 shows an earlier realization of the EDC environment (using SmartBoards). By using a horizontal electronic whiteboard (serving as the action space), participants work “around the table,” incrementally creating a shared model of the problem. They interact with computer simulations by manipulating the three-dimensional, physical objects that constitute a language for the domain. The position and movement of these physical objects are recognized by means of the touch-sensitive projection surface. Users construct a neighborhood design through the use of a physical language appropriate for the problem by placing objects in the action space. This construction is a description of the setting of concern to the stakeholders and becomes the object through which they can collaboratively evaluate and prescribe changes in their efforts to frame and resolve a problem. In the upper half of the figure, a second vertical electronic whiteboard (the reflection space) presents information related to the problem-at-hand for exploration and extension. In the figure, a user is filling out a survey in the reflection space that is constructed from the model presented in the action space. The results of this survey are stored (for future exploration) and are also fed to the simulation, where the ramifications of the decisions specified in the survey can be explored.

The reflection space is a separate client that connects to the simulation through a network link. It is primarily a web client that takes its cues from activity in the simulation. As a certain events in the simulation occur, the reflection space will displays information pertinent to that event. This information can either be pre-stored by an expert in the field, or can be fetched in real time from the web. The idea of the space is to provide useful information to the simulation participants so that they may “reflect” upon the action that they just performed. The space may also be used to keep statistics about the simulation such as average bus stop wait time per passenger, percent of land used for particular applications, etc.
Sketching

Previous use of SmartTech's SmartBoard supported sketching as well as interaction with the simulation. The sketching functionality was lost when we began to use the PitA-Board interface (see Appendix 2). After conducting a few tests of the new interface, several of the participants who had been involved with testing the previous system indicated that the sketching feature was useful and should be re-incorporated into the new system.

![Figure 3: The PitA-Board with sketch pen](image)

In order to add sketching to the new system, an eBeam electronic pen system was employed. This system tracks the movements of a special pen on the surface and sends the results to an attached computer. Currently the system uses a single pen, which provides a very different form of collaboration than the concurrent interaction supported by the Pita-Board. Rather than allowing multiple users to make changes at will, the single-pen interface forces a single participant to be in charge of making the changes at a given time, resulting in turn taking wherein users express their ideas, and then pass control to another user who may add to or modify the existing sketch. We are also exploring how the use of multiple pens might be incorporated.

The sketching interface involves a set of layers that store the currently displayed sketches, a library of saved sketches, and controls for color and height selection, new layer creation, and other utility functions. Currently displayed layers may be stacked upon each other on the display with the top layer allowing new objects to be sketched. Each sketch layer may be “set aside” or saved into the library for later reuse. The color picker allows the user to determine the fill color and line color they wish to draw with. The user may also select to change the pen to an eraser. The height attribute is used in the 3D visualization mentioned below. Utility functions such as layer creation, selection, and deletion are provided as well.

Sketches made in a layer can also be converted into an actual object in the simulation. By pressing the "make object" button and selecting a line or filled object from the sketch, the object is then imported to the simulation and can be used as an object (e.g., a road, a bus route, a land-use area—depending on the context) within the simulation.
Land Use Scenario

Extensive data are available from various sources, including local-government maintained GIS sources. Whereas this provides various “official views” of the area in question, there are other valuable perspectives that need to be brought to the table. To draw out these often-tacit sources of information, activities are needed to engage the participants in ways that surface disparate views and conflicts. For example, even though land-use data are available for our neighborhood, participants are asked to describe the “effective use” of their environment—how they perceive the use of land—by placing pieces representing land-use types (e.g., green for open space or yellow for single-family housing) on squares that they are familiar with (see Figure 4). As they proceed, there may be general agreement on the associations made, or there may be areas where one person’s description generates reactions from other participants that surfaces different understandings. One person may label the golf course as “open space,” which provokes another to pick up the “commercial” piece and state: “wait, they charge me money—it’s more of a commercial area.”

The information provided by the participants is shown on the board with the associated colors in a geographic view (see Figure 4) and is also shown in the reflection space (see Figure 5) in an analytic view (both tabular and graphical), summarizing how many of each land-use type has been labeled by participants.

---

**Figure 4: A Land-Use Scenario in the Action Space**

---

**Figure 5: Summary View of Land Use Generated in the Reflection Space**
Emerging Insight: Illustrating Multiple Walking Distances

Another activity used to engage participants in understanding the interaction among their preferences and perspectives is the walking-distance scenario. Participants utilize pieces representing themselves to indicate where they live on the map (resulting in a house icon appearing at that spot). They then use the “kiosks” located at the corners of the display, two with sun icons indicating “good weather” choices and two with cloud icons indicating “bad weather” choices. By placing their pieces on the appropriate kiosk, a menu of choices for distances ranging from 0 to 5 blocks appear, permitting them to indicate how far they would be willing to walk under the associated weather condition. After specifying this information, a colored circle appears around their house icon, indicating the range of area in which they might be willing to walk to catch a bus (see Figure 6).

![Figure 6: Walking-Distance Scenario](image)

As the participants all specify their information, the display shows emerging, overlapping patterns of areas that might be suitable for bus routes and bus stops, providing information and perspectives that no individual had in their head prior to the exercise.
Boulder City Council and University of Colorado Regents

In a rare event bringing together two stakeholders in Boulder’s community-oriented development, representatives of the Boulder City Council and the Regents of the University of Colorado gathered around the EDC action space (see article in Appendix 3) to discuss perspectives and explore computational models related to a design problem of common interest and concern. The shared space created a focal point for discussion, allowing participants to build common ground and explore possible resolutions to issues impacting both organizations.

Figure 7: Boulder City Council and University of Colorado Regents

The following two quotes from participants in this session reflect the strong positive impressions of EDC by members of those groups:

“The EDC would allow us to attract the maximum number of people to development and make improvements that are somewhat timeless in their dimension.”
— a Professional Campus Planner

“The EDC is an amazing, powerful tool that helps the entire audience to be on the same page and visualize what could be quite complicated drawings or renderings in a very easy format in which everyone ‘gets it’”
— a Professional Real-Estate Developer
Application Context — Emergency Management: Wildfires

The EDC Wildfire Simulation was conceived as an emergency-management training “flight simulator”—allowing group learning among experienced and novice wildfire managers in a context related to their area of interest.

The simulation provides

- Multiple map layers (with corresponding simulation data)
  - Topology: digital elevation, slope, aspect models
  - Fuels/vegetation model
  - Roads, city boundaries
- Simulation of wildfire behavior
  - Model- and data-based fire propagation
  - Control over wind direction
  - Control over initial placement of fires
- Specifying and simulating fire blocks
- Specifying and simulating evacuation routes based on population models
- Linkages to learning materials in fire/weather behavior on NCAR/UCAR’s Comet/MetEd online training.

Figure 8: A 3D View of the EDC Wildfire Simulation
Application Context — Emergency Management: Flooding

The EDC Flood Simulation was designed as emergency-management cooperative planning environment. It supports:

- Simulation of multiple flood stages as the flooding episode progresses
- Timed/randomly scheduled events (emergency calls, etc)
- Fire outbreaks caused by the flooding events
- Simulate player roles and actions (police, fire, EMS, NWS, city official, citizen)

to allow various stakeholders to participate in a tabletop exercise playing what-if games and scenarios, provoking discussion of what responses are appropriate and what improvements to response plans are needed.
**CARETTA: Integrating Individual and Social Creativity**

CARETTA is an extension to the EDC\textsubscript{F2F} (developed by Masanori Sugimoto, University of Tokyo) that integrates personal and shared spaces. CARETTA supports users in open-ended urban planning tasks, in which all participating stakeholders want to devise their “best” idea. To reach shared understanding and to make decision, the stakeholders need to discuss and negotiate their ideas and objectives. In actual group work situations, individual reflections and group discussions often happen in parallel: Some participants individually try to come up with their own ideas, and other participants collectively evaluate existing plans. Therefore, collaborative urban planning tasks are spiral and entwined processes that require the smooth integration of individual and group activities; outcomes gained through individual activities drive group activities and those gained through group activities trigger further individual activities. Existing computational media, however, do not fully support users’ individual and group activities at the same time because design trade-offs between them have been pointed out.

![CARETTA: Integrating Personal and Shared Spaces](image)

A personal space of CARETTA supports individual users’ reflection, because they can freely examine their ideas without being disturbed by other users. Providing each user with a personal space enhances the diversity of individual users’ activities: based on their knowledge and experiences, users can externalize and elaborate their own ideas that can lead to individual creativity. Providing users with the shared space allows design trade-offs between them to share physical boundary objects, and enhances interactions and negotiations among other users, that can lead to social creativity. By providing users with intuitive transition methods between the personal and shared spaces, CARETTA allows users to easily copy the current situation on the shared space (e.g. a design plan shared and discussed by a group of users) to individual users’ personal spaces, and display design plans devised by individual users on their personal space onto the shared space. Therefore, CARETTA can support users in seamlessly conducting their tasks on both these spaces, and enhances collaborative problem solving processes in which individual and social creativity is required.
3D Visualization

The ability to change perspective in an urban planning project is an obvious necessity. Early work on this extension was done using OpenGL, but was set aside with the availability of Google Earth. By providing KML objects from the simulation, view control, 3D objects, and image overlays can be relayed to a Google Earth client. The current solution employs three separate sockets to handle three of the data streams, each of which is refreshed by the Google Earth client on a periodic basis. By providing this stream separation, the end user can subscribe to the data he is interested in, and can turn off various streams, such as view control, so that he may change the perspective to his personal preference.

![Google Earth Visualization Client](image)

**Figure 10: Google Earth Visualization Client**

The KML feeds have been separated as follows:

- **Control** - users control the viewpoint of the camera using pieces on the board (see following paragraph).
- **3D Objects** - things such as buildings generated from sketching, or placement of predetermined pieces (such as one representing a house).
- **Overlays** - All of the image data projected onto the earth surface.

Immediate 3D visualization is available through a local Google Earth client, which is projected for all participants to observe. Control of the view is done through two designated pieces, and the context of the 2D view. The "camera" for the Google Earth client is centered on the same location as the 2D view, and is positioned according to the location of the designated pieces. The view pieces differ only in view angle, one of which provides a "helicopter" view and the other provides a ground level view. As the 2D view is zoomed in or out, the range of the camera from the center point is decreased or increased respectively, effectively providing the same scaled view as the 2D version.

Multiple clients can be supported to provide remote meeting capabilities, and further capability can be added by using the PDA client (mentioned above) with a Google Earth client.

All of the sketches, as mentioned before, have an associated height. As can be seen in the sketching image above, the buildings have been sketched into the simulation using the pen. When these are shown in a Google Earth 3D view, the height differences become evident, allowing participants to better visualize the impact of their design conjectures. Note the overlay identical to that used in the action space has been placed beneath the sketched buildings in the Google Earth view.
Extending Participation with the EDC<sub>VR</sub>

Our work on the EDC to this point has focused primarily on face-to-face meetings with EDC<sub>F2F</sub> and has been studied in demonstration and role-playing settings by engaging authentic and semi-authentic participants in the use of the system in one- to two-hour sessions.

The focus on face-to-face interaction has resulted in a limited scope of participation. To make the EDC more viable by enabling participation beyond co-present settings, we will transcend the constraints of EDC<sub>F2F</sub> by extending the participation opportunities into the virtual-reality sphere by designing and developing the EDC<sub>VR</sub>, utilizing opportunities represented by SECOND LIFE and the emerging open-source OPENSIM effort. With EDC<sub>VR</sub> we will expand our test-bed environment to instantiate, evaluate, and further develop our theoretical framework for how to design appropriate socio-technical environments for participative roles and migration among them. The new and existing versions will be used to compare and contrast various aspects of participation.

![Figure 11: The Integration of Different System Components in the EDC](image)

The ability to allow more people to participate represented by the EDC<sub>VR</sub> and the utilization and development of substrates that support a range of roles will provide an environment to study and develop specific interventions to encourage and cultivate increasing involvement.

We will build on research that has shown how the “online” and “offline” social worlds are related—and how they are different. To understand the evolution of new forms of social interaction in on-line virtual reality and their historical and continuing relations to the off-line world, the EDC<sub>VR</sub> will be integrated with the EDC<sub>F2F</sub> to form an EDC<sub>HYBRID</sub>. This will allow on-line, face-to-face, and combined participation to take place, building synergy between the strengths of the respective environments and allowing the study of the impact of these approaches on role development and migration. One aspect of this hybridization is shown in Figure 11, pane (a), with a mockup of a portal into the EDC<sub>VR</sub>, as shown in a reflection space display. These developments will extend the EDC to include greater flexibility and explore the way in which technical and social infrastructures can be integrated to sustain usefulness, sociability, and meaningfulness and thus create new prospects for social creativity and collaborative design.

The EDC will be extended with the creation of physical objects that are active and controllable rather than limited to being sensed and tracked (for example, a bus in a transportation design can be equipped with a motor and steering).
Appendix 2: Brief Description of Technical Aspects of the EDC/PitA-Board
(Viewable on-line at http://L^3.cs.colorado.edu/systems/EDC/PitA-Board)

Synopsis

In the context of the Envisionment and Discovery Collaboratory, we have been working to create an action space that supports more direct interaction of a group of individuals with computational simulations in a face-to-face environment. This has led to the development of the "Participate-in-the-Action (PitA)"-Board.

Initial prototypes of the EDC system were based on a touch-screen technology (SmartTech's SmartBoard) placed in a horizontal orientation, which afforded insights into important aspects of the around-the-table interaction. This revealed several limitations, such as problems with simultaneous interactions and the inability to create interaction behaviors more closely tailored to the objects the user is interacting with.

We are currently using a technology created for electronic chessboards (by DGT Projects, NL) that allows several objects (with embedded transponders) to be tracked simultaneously. Each object can then be given a particular form of behavior by the software system.

To restore the sketching capability that the new system lacks, we are working with electronic pen technology that will allow users to "sketch" their ideas and define objects within a simulation (eBeam).

Areas of Application

We are exploring the use of this technology in numerous contexts where collaborative or participative interaction is a critical aspect of the design process. Possibilities that are being investigated include:

- Transportation planning and design, such as the FasTracks project in the Denver Metro Area
- Innovative transportation-oriented development projects, requiring participation and buy-in from numerous constituencies, across various design phases.
- Wildfire management, preparation, and mitigation efforts ranging from training to community awareness
- Natural heritage appreciation, preservation, and community support, such as the Silence of the Lands project

System Architecture. The current system is composed of multiple interacting components. The core of the system, The Pita Simulation (PitaSim), is responsible for querying the PitA Board for piece changes, interpreting user input from the eBeam system, and communicating with any visualization, reflection, or PDA clients.

Software. PitaSim is constructed using Squeak, a Smalltalk media environment. The use of Squeak allows for the rapid development of a graphical interface, hardware drivers and network connections. Squeak allows for relatively easy creation of simulations, such that real world situations can be modeled by simply defining a few objects and their relationships to each other. Squeak runs on a virtual machine, enabling almost any system to run any one of the PitA servers and clients.

PitA-Board. The current PitA-Board is composed of 4 DGT Projects chessboards linked together and placed in a custom table. Each of the chess pieces contains an RF circuit with a unique signature that allows for 15 different unique inputs per context, and any number of pieces with the same signature. The board is limited in its immediate resolution to the chessboard square size, but provides an advantage over
the older models in that several users may input to the simulation simultaneously. An overhead projector linked to the PitA simulation server provides the users with visual feedback on the board, and outlines the grid that a piece may be placed into.

**PitA PDA Client.** In the interest of allowing the technology to be used to support the integration of personal and shared interaction spaces, a PDA client was created to disperse information and voting control to a larger group of participants. As conceived, the PDA client would allow participants to interact with information on an individual basis as well as in the shared interaction space. Each client also has the ability to electronically announce its presence so that the simulation would be aware of a new participant, and be able to send a summary of the simulation thus far so that the user may get caught up.

A secondary use for the PDA client is for input to the simulation. A user may place a piece or "wand" onto the space in the simulation he or she wishes to modify. That user's PDA will then be granted permission to modify the space or any object occupying that space. Given this scenario, one can imagine one of many uses being for the user to be able to specify certain information about his or her own house. By placing the wand on his or her house, the user might then be prompted to enter information such as number of occupants, cars, etc on his PDA.

### Appendix 3: Article in CU's Engineering College’s Alumni Focus

**Research Focus: Natural Disasters**

**Center for LifeLong Learning and Design Hosts Boulder Officials for Emergency Planning Sessions**

At first glance it may resemble a tabletop computer game, but the PitA-Board in CU's Center for LifeLong Learning and Design may become the latest tool in Boulder's emergency planning tool belt.

An acronym for "Participate-in-the-Action," the PitA-Board is a highly sophisticated and interactive information technology tool, bringing real-time data in the form of GIS maps about everything from housing and transportation to flood and wildfire risk potential to the table—literally.

Based on touch-screen technology created for electronic chessboards, with additional capabilities such as sketching and tilting to provide different points of view, the system can be used to test different scenarios and even conduct real-time management of events.

City and university officials gathered around the PitA-Board on multiple occasions this fall to see how the technology could assist them in taking community and emergency planning to the next level.

"This would be an outstanding tool to show simulations to the community so that people would know what to do in the event of an emergency," Assistant City Manager Stephanie Gauthier said at a session in October. Explaining that the city recently held a meeting to discuss what they learned from Hurricane Katrina that could apply to local emergency planning procedures, she said that city officials know what residents would do in certain emergencies, but the general public is not well enough informed. City officials also are considering how they might adopt the technology to improve personnel training and to evaluate and update the city's strategic plan.

CU and Boulder city officials gather around the PitA-Board to discuss planning issues this fall.

Center Director Gerhard Fischer and Associate Director Hal Eden said they want to build partnerships with the city and other groups to help push the technology forward. Researchers already have worked extensively with a wildland fire group at the National Center for Atmospheric Research to develop the technology's potential in that area.

http://3id.cs.colorado.edu/systems/EDC/Pita-Board