Ligature: Gesture-Based Configuration of the E21 Intelligent Environment

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1. Media Devices in E21

The E21 intelligent environment is a 6.4 m by 3.6 m conference room located at the MIT Artificial Intelligence Laboratory (Figure 1). The room is augmented with a variety of media input and output devices, including backroom computers, a DVD player, LCD projectors, and Mimio[1] digital whiteboards. The space is flexibly reconfigurable in software, enabling devices to be turned on and off, and audio, video, and pointer events rerouted among them, all under software control.
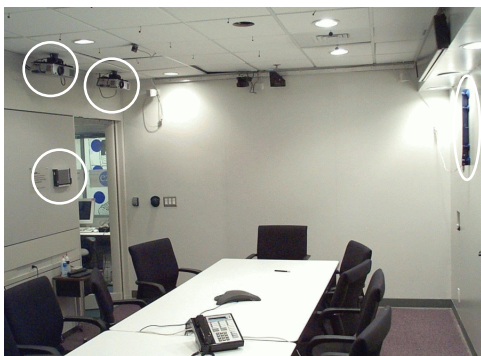

Figure 1. The E21 environment and some of its devices. LCD projectors are highlighted at upper left; the pen computer at left; and the Mimio at right.

Presently, devices and device connections are controlled by a combination of voice commands, manual control (i.e., pressing a button), and interaction with an HTML form interface on wall-mounted pen computer (see Figure 1). This abstract describes Ligature, a prototype interface that allows a user to monitor and reconfigure the room's devices through a gesture-based interface. I believe such an interface has the following advantages for device configuration: (1) the user can easily assess the current state of the devices in the space; (2) a connection can be created or removed with a single pen stroke, providing a consistent, direct-manipulation interface for configuring the space; and (3), configurations can be saved and later recalled, to preserve users' preferences in the space.

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[1]Trademark of Virtual Ink, Inc.

2. Media Types

A media type system was developed to support the Ligature prototype. The media type system ensures that connections are made only between compatible devices (i.e., the S-Video output of the DVD player only to displays that can accept S-Video). The purpose of the type system is to provide the user with a valid set of choices when making a connection with a device. The prototype assumes that there is a switchable physical connection between every pair of compatible devices in E21.

Each connectible device in E21 is represented as a node that can be a source (has outputs) or a sink (has inputs). A source has media types that describe the signals it outputs, while a sink has media types that describe the inputs it accepts. Both sources and sinks have an arity, indicating the number of connections that can be made to or from that connector. For example, the speakers have a maximum input arity of ∞, because all audio outputs are passed through a mixer that drives the speakers.

Generally, the media types may be arranged in a tree according to a subtyping relation $\subseteq$. For example, speakers which accept `audio-5.1` can also accept `audio-mono` and `audio-stereo`, so `audio-mono` $\subset$ `audio-stereo` $\subset$ `audio-5.1`.

A configuration is a set of source and sink nodes and the connections among them. A configuration is valid if and only if the type and arity constraints are obeyed: for every connection from source O with type T_O to sink I with type T_I, $T_O \subseteq T_I$; and for every source or sink A with n connections, $A_{min} \leq n \leq A_{max}$. Table 1 lists the devices in E21 that are included in this type system.

3. Gesture-based Control

Ligature currently supports three gestures. Selection is performed by tapping a device on the map, which is then highlighted. Each device that can be connected to the selected device is also highlighted on the map, according to the current configuration. This is done by checking to see if a new connection to the device would create a valid configuration.

A connection is made by dragging the pen from one device

Table 1. A catalog of E21 devices, their media types, and arities.

Source	Output Types	Arity
Backroom Computer	`video-vga,` `audio-stereo`	$[0, \infty]$
Laptop VGA Port	`video-vga`	$[0, 1]$
DVD Player	`video-svideo,` `audio-5.1`	$[0, 1]$
Microphone	`audio-mono`	$[0, 1]$
Mimio	`mouse`	$[0, 1]$
Laser Pointer Mouse	`mouse`	$[0, 1]$
Wireless Keyboard	`mouse+keyboard`	$[0, 1]$
Sink	**Input Types**	**Arity**
Backroom Computer	`mouse,` `mouse+keyboard`	$[0, 1]$
Backroom Computer	`audio-mono`	$[0, 1]$
Center Projector	`video-vga,` `video-svideo`	1
Other Projectors	`video-vga`	1
Speakers	`audio-5.1`	$[0, \infty]$

to another. If the devices are compatible, a new connection is made and the display updated. Other devices may be disconnected according to the arity constraints in the configuration. For example, making a new connection to a projector (which can only display one input at a time) will remove any previous connections to that projector.

Connections may be drawn in either direction; Ligature deduces the correct connectors for devices with multiple inputs or outputs. If the user's intent is ambiguous, a single physical device can be split into multiple logical devices to provide more precision.

Finally, devices are disconnected by drawing a short stroke that crosses a connection on the map. A user may also save the current configuration along with an identifying sketch. The user can later browse saved configurations, and load one to restore its connections. Examples of these uses of Ligature are shown in Figure 2.

4. Current Status and Future Work

Presently, the Ligature prototype supports the virtual interconnection of E21's projectors and the backroom computers, but no physical connections are made. The next step is integrating Ligature with the Metaglue agent system (Coen et al., 1999) to (1) find the devices in the room and their physical coordinates, and (2) use Rascal, Metaglue's resource management system (Gajos & Weisman, 2001), to query and change device connections. This functionality will replace the handcoded map and media type system used in the prototype.

A future enhancement to the interface is to include devices with states (e.g., the lights). An informal usability study is also planned to evaluate the effectiveness the interface, as well as to gather suggestions from its users, which include both the users and maintainers of E21.
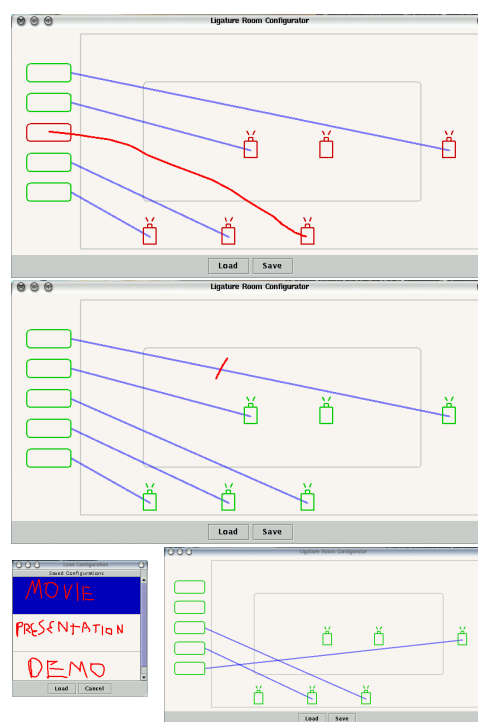

Figure 2. Usage examples. Top: making a new connection. Middle: removing a connection. Bottom: loading a saved configuration.

A goal of the E21 project is a self-configuring intelligent environment, whose users give a high level task description and let the environment configure itself to support that activity. An intermediate step is an interface like Ligature to visualize and manage the space and its devices. As the space becomes more self-configuring, such an interface remains useful for users who wish to personalize their environment. Long-range plans are to multimodally configure services and applications, as well as devices.

Acknowledgments

References

Coen, M., et al. (1999). Meeting the computational needs of intelligent environments: The Metaglue system. *Proceedings of MANSE'99*. Dublin, Ireland.

Gajos, K., & Weisman, L. (2001). Rascal – a resource manager for E21. *Proceedings of MIT Student Oxygen Workshop 2001*. To Appear.