Ligature: Gesture-Based Configuration of the E21 Intelligent Environment

Mark A. Foltz MFOLTZ@AI.MIT.EDU

MIT Artificial Intelligence Lab, 200 Technology Square Room NE43-808, Cambridge MA 02139 USA

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 computer workstations, 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.
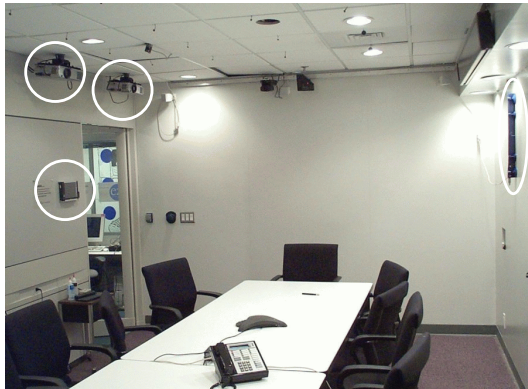

Figure 1. The E21 environment and some of its devices. LCD projectors are highlighted at upper left; the pen computer at left; and the Mimio at right.

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

The interface uses a media type system to ensure that connections are made only between compatible devices (i.e., the video output of the DVD player only to the displays that can accept that output). The purpose of the type system is to provide the user with a valid set of choices when making a connection with a device.

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

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, $A_{min} \leq n \leq A_{max}$.

The source and sink devices in E21 that are planned to be added to this interface are listed in Table 1.

3. Gesture-based Control

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

A connection is made by dragging the pen from one device 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)

Table 1. Partial catalog of connectible E21 devices. Not all of these are included in the present prototype.

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`	$[0, \infty]$

will remove any previous connections to that projector.

Connections may be drawn in either direction. Ligature also deduces what inputs and outputs are used to make the connection, for devices with multiple inputs or outputs. This may cause the user's intent to be ambiguous in some cases (but these cases have not yet arisen).

Finally, devices are disconnected by drawing a short stroke that crosses a connection on the map.

The interface also supports the saving of the current configuration along with a sketch to identify it. The list of saved configurations can be browsed later, and a configuration loaded to restore the saved state of the environment.

Examples of these uses of Ligature are shown in Figure 2.

4. Current Status and Future Work

Presently, the Ligature interface supports the visual interconnection of E21's projectors and the backroom computers, but no actual connections are made among the physical devices. The next steps for this work are 1. extending Ligature to include more devices in its interface, and 2. integration with the Metaglue agent system (**?**). Each E21 device has a corresponding Metaglue agent, which provides a software API to control the device. Once these steps are taken, Ligature can be installed on the wall pen computer in E21.

A future enhancement to the interface is the visualization and control of devices' states, as well as their connections. For example, if a connection is made to a projector that is currently off, the projector should be automatically turned on. 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

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

maintainers of E21.

Part of the eventual vision of the E21 project is for the room to be self-configuring, so that its users can give high level task descriptions and the room automatically configures its devices to support their activity. An intermediate step is an interface like Ligature to visualize and manage the room and its devices. Once the room becomes more self-configuring, such an interface remains useful for users who wish to personalize their environment. Long-range plans are to enable the multimodal configuration of services and applications, as well as devices.

Acknowledgments

References

Coen][1999]coen99 Coen, M. H. (1999). Meeting the computational needs of intelligent environments: The Metaglue system. In submission.