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BrlAPI: Simple, Portable, Concurrent, Application-level Control of Braille Terminals

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Abstract

Screen readers can drive braille devices for allowing visually impaired users to access computer environments, by providing them the same information as sighted users. But in some cases, this view is not easy to use on a braille device. In such cases, it would be much more useful to let applications provide their own braille feedback, specially adapted to visually impaired users. Such applications would then need the ability to output braille ; however, allowing both screen readers and applications access a wide panel of braille devices is not a trivial task.

We present an abstraction layer that applications may use to communicate with braille devices. They do not need to deal with the specificities of each device, but can do so if necessary. We show how several applications can communicate with one braille device concurrently, with BrlAPI making sensible choices about which application eventually gets access to the device. The description of a widely used implementation of BrlAPI is included.

1. Introduction

Usually, visually impaired people use computers with the help of special programs called screen readers which deliver the information displayed on the screen using a speech synthesis system or a refreshable braille display. Designing screen readers able to communicate with different brands of braille display was so difficult that until recently screen readers could only work with one brand of braille terminal. It was then usual for a manufacturer to provide both a braille terminal and a

screen reader using it. Only the most recent screen readers support several brands of braille terminals.

However, even with these newer readers, there is a deeper problem that remains unsolved: visually impaired people are forced to use exactly the same interface as sighted people, since there is no standard mechanism for an application to provide an alternative, more suited interface in addition to the standard screen-based one. One part of this problem lies in the fact that there is no way for applications to communicate directly with braille terminals, since these are being used exclusively by screen readers.

The BrlAPI framework that will be introduced in this paper can be seen as a first step towards the resolution of this problem. Indeed, it proposes a client-server approach that lets applications communicate with braille terminals thanks to a server that both removes the need for applications to know exactly how to communicate with each braille terminal and lets several applications share the braille device. Device-specific applications like file transfer tools are not neglected either, since BrlAPI offers a way for such programs to communicate directly with the device.

In Section 2 we discuss in greater detail the problems that are specific to braille display. Section 3 describes the BrlAPI solution; an implementation of this solution is presented in Section 4. Finally, Section 5 presents the current clients of BrlAPI, and Section 6 gives some concluding remarks and lists a few remaining open questions.

2. Issues for Driving Braille Devices

The question of accessing a braille display within an application is not trivial, mainly because of the large variety of available models, and because of the problem of properly sharing one display between several applications. Protecting the access to braille displays must also be considered.

2.1. Heterogeneity of Braille Devices

Every braille terminal has a refreshable braille display divided into eight pin cells; however, the number of available cells and their layout vary from display to display. Some terminals have a unique display, others have two (the main one, generally used to display a small region of the screen, and an auxiliary one, usually used to report status information like cursor position or current time). Some modern devices also let users adjust the firmness of braille dots to either display hard and easy-to-read dots when the display is connected to a power source, or softer dots when the display is unplugged, to save energy.

Perhaps more importantly, braille terminals come with very different keyboards. Some terminals which are also used as note-takers include a keyboard to write characters (either in braille or through a more standard PC-like keyboard). In addition to these optional keyboards, braille terminals have function keys whose number and layout is, again, terminal dependent. Manufacturers of braille terminals have shown a rather vivid imagination regarding the kind of available function keys: simple keys, keys associated with braille cells (usually called routing keys because one of their functions is to bring the cursor to the character displayed by their associated cell), joysticks, navigation bars that can be moved one or two steps in each of four directions, wheels, *etc.* To sum up, braille keyboards can be much more complex than plain PC keyboards. In fact, they often provide the functionality available both through a keyboard and a mouse.

Last but not least, there is no standard way to communicate with a braille display. Each manufacturer has designed its own communication protocol to let its braille devices receive text to display or configuration information and to send keyboard events or report status information.

Hence, the first problem one encounters is that braille terminals form a completely heterogeneous class of devices. How should displays be accessed? How should keyboard events be delivered? Should they be rather driver specific (each application then has to interpret them in a consistent manner), or should keyboard

events be described in a more standard way, in spite of their potentially different nature ?

2.2. Concurrency

Another issue is that modern operating systems let several applications run concurrently, their visual output being usually sent to separate virtual terminals or windows. Some of these applications may want to use the braille device for providing more appropriate braille output. A visually impaired user may also want to use several screen readers simultaneously, in order to get the best benefits from each of them. This results in a concurrency issue: what should eventually be displayed on the braille terminal? To which application should the key events be directed?

Moreover, one may want to write some applications dedicated to a given brand of terminals, that would take full control of the braille device. For instance, note-takers can often exchange files with the computer, through a brand-specific protocol. So as to avoid corruption during the transfer, all other device operations should be suspended, but the applications that requested them should not have to be aware of that.

2.3. Protection

Usually, input/output devices such as keyboards and screens are controlled by the operating system's kernel. Each user process has to interact with the kernel to perform input/output. Therefore, it is unlikely that a user process can access these devices in a way which would render them unusable. This, however, is not true for braille devices. Indeed, they are generally handled by a user-mode process, since this makes development and distribution easier. As a consequence, braille terminals are much more vulnerable than more traditional input/output devices to incorrect use by other processes. Given that incorrect use can damage a braille terminal irreversibly, and that these devices are extremely expensive, it is important to ensure good protection of this resource against incorrect usage or malicious intent. This need for good protection becomes even more critical in the context of modern multi-user networked operating systems.

3. Proposed Solution

For tackling all the issues described in the previous Section, we propose the BrlAPI framework, based on a client-server approach. A BrlAPI server uses a driver for controlling the braille terminal, and applications connect to the server for interacting with the

braille device. This even allows an application running on one machine to drive a braille display connected to another machine, provided that the two machines are interconnected by a network link.

3.1. Handling the Variety of Terminals

The BrlAPI server has a series of drivers, each of them knowing how to communicate with one given family of braille devices. More precisely, the server is able to send text to display, and to receive key events. Optionally, a driver can also provide lower-level, packet-based input/output functionality. In practice, one running instance of the BrlAPI server communicates with *one* braille device.

When clients connect to a server, they can request the dimensions of the corresponding display, and then perform `write` requests.

Moreover, clients can query the server for the name of the braille device it is communicating with. This permits a client to decide how it wants to receive key events. Key events can be delivered to a client application in two different ways.

First, the server can deliver key events it gets from the device as-is. This presupposes that client applications know exactly how key events are returned by the braille driver they are talking to, and lets developers use the knowledge of some given keyboard when designing their applications.

Second, key events can be converted to a standard representation by the server before being delivered to a client. For instance, braille devices often have keys typically used for browsing the current line, going to the next or previous line, *etc.* Clients can then be written independently of the braille device, their use remaining easy and intuitive. This also favours a semantically consistent use of keys from one client application to another.

3.2. Selecting the Proper Application

Previous work like Libbraille [12] achieved results similar to those described in Section 3.1. However, the context of Libbraille was the TIM project [2], in which only one application needed to be run at a time. As a result, Libbraille was intrinsically not designed to allow several applications to control the braille terminal.

In contrast, thanks to the client-server design, several applications can connect to the BrlAPI server. Each application behaves like if it were the only one that has access to the braille device, but the BrlAPI server actually *switches* between applications as appropriate. Only one application at a time has the “focus”, which means

that its output is actually sent to the braille device, and braille key events are sent back to it. Output of each other application is stored and will be displayed later, when they get the focus again.

What “appropriate focus” may mean is not completely clear. One natural way of switching between applications is to just follow the already well-known keyboard and mouse focus. This is necessary when using braille terminals which do not have an integrated keyboard, since the regular keyboard then has to be used. Nevertheless, even when using a braille terminal with an integrated keyboard, it is a lot easier for a visually impaired person to work with a sighted person if the notion of *focus* is the same for both of them. It should be noted that this is different from the situation of dispatching speech synthesis [6]. The reason for this is that speech naturally expresses *time*, while braille naturally expresses *space*.

The solution we adopted is hence to require applications, before issuing write requests or starting to wait for key events, to declare “where” they are running, this being expressed as an integer, and the BrlAPI server just needs to find out where the keyboard and mouse focus is. In the case of the Linux console for instance, this is the number of the Virtual Terminal (VT) in which the application is running, and the BrlAPI server just asks the kernel which VT is active. In the case of an X-Window desktop, this is the ID of the window in which the application is running, and a dedicated X-window application called `xbrlapi` sends to the BrlAPI server the ID of the active window. The user can hence just switch between consoles and windows as usual, and the braille device will always display the appropriate application’s output.

The notion of focus is even nested by having applications actually send a list of integers: an application running on VT 2 will send a 1-element list just holding 2, while an application running in a window of an X server that is running on VT 7 will actually send a 2-element list holding 7 and the window ID. The BrlAPI server just has to first find out which VT is active, and if this is VT 7, find out which window of the X server is active.

Finally, as was mentioned in Section 2.2, some specialized applications like file transfer tools may have to take full control of the braille device. With our client-server approach, we check that only one application at a time requests such control, and disable all braille driver handling except the basic low-level device protocol operations like splitting data coming from the device into packets (if the device protocol is packet-oriented). The application can then send raw data to the braille driver, which in turn sends it to the device. Symmetrically, data

that the braille driver receives from the device is passed back to the application. This way, applications can easily implement file transfer protocols for instance.

Furthermore, applications can even switch to the “suspended mode”, in which the BrlAPI server keeps its braille driver shut down, so that the application may open the device itself and thus be free to totally control it.

The XVI [4] client-server design is similar to ours, but though it permits several clients to connect concurrently, it does not perform an automatic switching between them. It also does not allow applications to take full control of the braille device.

3.3. A Simple Interface for Programmers

In order to achieve the various actions explained above, applications actually switch between the following modes.

Tty mode: The application may issue `write` requests for displaying text on the braille display, and may receive `key` events.

Raw mode: The application directly communicates with the braille device through the BrlAPI connection.

Suspended mode: The BrlAPI server keeps its device driver shut down, letting the application directly open the device itself.

For instance, the following simplified code snippet connects to the server, writes a prompt and waits for a key:

```
brlapi_openConnection();
brlapi_enterTtyMode();
brlapi_writeText("Press any key");
brlapi_readKey(&code);
brlapi_leaveTtyMode();
brlapi_closeConnection();
```

3.4. Protection

BrlAPI includes an authorisation mechanism used by the server to decide whether a client is allowed to connect or not. The precise authorisation procedures are left unspecified, so that various authorisation procedures can be implemented according to what the operating system supports (`SO_PEERCREC`, `getpeereid`, etc.). When a client connects, the server advertises the list of supported authorisation mechanisms. The client uses one of them, and if the authorisation procedure succeeds, the connection is accepted. Otherwise, the client may try a different mechanism.

4. Implementation

BRLTTY [9] is a portable screen reader: it works on Linux, all BSD flavors (including MacOS X), Solaris, OSF, HP-UX, QNX, Windows, Hurd, DOS. It also supports a wide range of braille terminals (around 50 models). The BrlAPI framework was hence implemented within BRLTTY. A BrlAPI server is implemented within the screen reader in an independent thread, and a library is provided so that applications can easily act as BrlAPI clients. Bindings for this library have been written for Python, Java, TCL and Common lisp. Bindings for some other languages (Objective Caml, Perl and Haskell) are currently in development.

When both clients and server are running on the same machine, either a Unix local socket or a Windows named pipe is used to establish the connection. In some cases (just like with X-window applications), clients may have to run on another machine. In this case, a TCP/IP connection is used instead. A range of ports has been reserved at IANA [5] for this purpose. In order to reduce the risks inherent in text parsing and to keep the server simple, we use a binary protocol over this connection. No encryption is performed, since just like X, it would be easy to encrypt the connections using external tools like `ssh` or IP-layer encryption.

Finally, the communication protocol has been designed to minimize the number of packets to exchange between client and server in situations where performance matters. For instance, `write` requests emitted by a client require no acknowledgement from the server. If the `write` fails for some reason (e.g. inconsistent data are sent), an error will be reported *asynchronously*.

5. BrlAPI Clients

The BrlAPI framework is already widely used on Linux systems as a means for screen readers to drive braille devices. This includes X-window readers like Gnopernicus from Baum [3], Orca from Sun [11] and LSR from IBM [8], as well as the Emacs reader `speechd-el` [7]. This permits not only to avoid having to re-implement device drivers, but also to cooperate harmoniously with the Linux text console: BrlAPI allows switching between the BRLTTY reading of Linux text consoles and the reading of X or Emacs Windows. The `gnome-braille` [10] braille translation library also uses BrlAPI as one of its output devices.

Some file transfer applications have been developed and are now used on a daily basis: `vbtcp` for Visio-Braille devices, `trf` for EuroBraille devices, and soon `htcom` for HandyTech devices.

Also, the `bless` client is a little braille-enabled

replacement for the well-known `less` Unix command. Currently, it lets visually impaired persons read documents without having to scroll the screen, and allows them to save their current position in a document in order to come back to it quickly later.

Finally, it is worth mentioning that the Accessibility Free Standards Group [1] is even considering adopting BrlAPI as its standard braille I/O sharing component.

6. Conclusion

The large diversity of braille terminals makes it especially difficult to design a generic communication interface which also allows the use of advanced capabilities provided by each terminal. Allowing several applications to access a braille display concurrently, and in a way that protects the display from incorrect use are two other important problems. BrlAPI solves these problems by relying on a client-server approach: each application connects to a server, which is responsible for abstracting away the details of each device and decides which application should, at any moment, be allowed to communicate with the device. That way, the end user doesn't have to care at all: she can just switch between consoles and windows as usual, the braille device will always display the appropriate information. An implementation of the BrlAPI server has been integrated to the BRLTTY screen reader, and a library has been provided to help client applications communicate with braille devices through BrlAPI. Currently, BrlAPI is used by several screen readers for graphical environments.

It has been suggested that instead of using a client-server approach, we could instead define a TTY terminfo entry, and applications would not have to be modified: they would simply notice that they are running in a very small terminal (compared to the usual 80x25 ones). However, since applications have only one standard output, that would also mean that sighted users would be restricted to this output.

Although we are fully convinced that BrlAPI is a mature project, we also think that a number of things remain to be done. For a start, many users and developers would like to be able to spatially share a braille window. Instead of using the whole display as is the case for now, applications would be given the control of only one region of the display, leaving the other regions available for other applications. This would not only be interesting for multi-line displays; it would also be useful on long single-line displays, to reserve the rightmost part for displaying the current time on those braille terminals that do not include status cells.

It would also be useful to write a detachable multiplexer. It would for instance be run along with the `screen` program and allow the running of applications in a "detached" session and let the user reattach the session, including the BrlAPI applications.

Furthermore, we would like to let applications configure and request the properties of the BrlAPI server. These would of course include the name of the currently loaded braille driver, the size of its braille display and the current braille table (which defines the mapping between characters and their braille representations), but also the cursor blinking rate and shape, the braille contraction style, etc.

Yet another capability we may add to BrlAPI is support for graphical braille displays. Indeed, in Section 2.1, we asserted that braille displays are divided into eight-pin cells. However, this is not always true as some terminals with a matrix of pins have been designed, their goal being to display figures and graphical information. Although this kind of terminal is rare, the situation may change in the future, hence the need for BrlAPI to support them too.

Eventually, we would like to integrate the BrlAPI protocol directly into X and TTY streams. That would solve a lot of focus and authorisation issues.

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