Controlling Projector Automatically from Raspberry Pi

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Abstract

The objective of this experiment is to discard the laborious task of manually turning on/off a projector when delivering presentations on a Raspberry Pi. The approach undertaken to automate this is to catch HDMI connect/disconnect events and send appropriate signals to the projector through an IR Transmitter.

1 Preparation

- Installed LIRC packages on Raspbian Buster with kernel 4.19.75-v7+ with a patch(1).
- Issued IR Emitter (IR333-A) and GPIO Utility Board with IR Receiver (TSOP1738).
- Revised slides: part08-udev, part16-pin, part17-dts, part18-libgpio, part21-lirc.

2 Procedure and Test Cases

- Setup the IR Transmitter circuit; with a 5V source (in my case its from the RaspberryPi itself), a 400ohm resistor, a NPN transistor and an IR emitter (detailed schematic is given in 3.2 section).
- Connect the RaspberryPi to a power source (in my case its a laptop) with the loaded modules ('ssh' with Ethernet cable could be used for debugging) and ensure the initial state of the whole setup is that the projector is ON and the HDMI cable is connected.
- Ensure the IR emitter is directed towards the projector and there's no obstruction in-between.

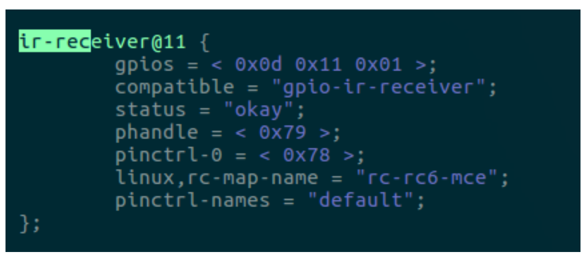
- The expected output is that once we disconnect the HDMI connector for the RaspberryPi, the IR emitter sends a POWER_OFF signal (can be seen through a phone camera with no IR-filter) and the projector turns off after 3-4 secs (depends on polling frequency) of the disconnect event. In the case of plugging in the HDMI connector when the projector is OFF (red light), the IR emitter should send POWER_ON signal and the projector should turn on in 3-4 secs.

3 Experiments and Analysis

3.1 GPIO

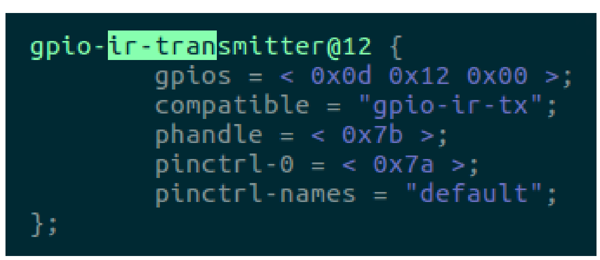
“GPIO is half-baked hardware” - with this statement in my head, I set out to discover how one can setup functions for a GPIO cell to act like an IR receiver and a transmitter. I figured de-compiling the device-tree (which is currently being used by the kernel) to check for overlays that have defined the GPIO pin numbers for IR-rx and IR-tx could be a valid approach.

$ sudo dtc -I fs /sys/firmware/devicetree/base -O dts -o loaded_device_tree.dts
saved my de-compiled device-tree in ‘loaded_device_tree.dts’. There I looked for ir-rx and ir-tx which gave me:



```
ir-receiver@11 {
        gpios = < 0x0d 0x11 0x01 >;
        compatible = "gpio-ir-receiver";
        status = "okay";
        phandle = < 0x79 >;
        pinctrl-0 = < 0x78 >;
        linux,rc-map-name = "rc-rc6-mce";
        pinctrl-names = "default";
};
```

Figure 1: ir-receiver@11 in loaded_device_tree.dts



```
gpio-ir-transmitter@12 {
        gpios = < 0x0d 0x12 0x00 >;
        compatible = "gpio-ir-tx";
        phandle = < 0x7b >;
        pinctrl-0 = < 0x7a >;
        pinctrl-names = "default";
};
```

Figure 2: gpio-ir-transmitter@12 in loaded_device_tree.dts

Here, we can see that receiver is to be connected to GPIO 17 (0x11) and emitter at GPIO 18 (0x12). The same information is available in /boot/overlay/README (under gpio-ir and gpio-ir-tx). Although to enable infrared communication and for the overlay to take reflect in the device-tree, one had to uncomment a few lines in /boot/config.txt (and then reboot for the new device-tree to be picked up by the kernel) as shown here:

```
# Uncomment this to enable infrared communication.
dtoverlay=gpio-ir,gpio_pin=17
dtoverlay=gpio-ir-tx,gpio_pin=18
```

Figure 3: After uncommenting; to enable infrared communication.

I also examined the description of the device-tree bindings (2) (3) for more clarity on how the IR rx and tx works before proceeding with the practical experiments.

3.2 LIRC

I, first, set up the initial circuitry composed of only the IR rx to decode the 38KHz infrared signals from the CASIO projector's remote using lircd daemon. I noticed the device special file created by LIRC driver: /dev/lirc0 (Tx) and /dev/lirc1 (Rx) were exposed in devfs, as discussed in the class. To see the receive raw (pulse-space) codes from the remote, I used the command line utility provided by LIRC: mode2. Although, that didn't work as expected even after numerous tries and re-reading the man pages. The output I was getting were decoded keycodes which were also different everytime even for the same button press, as shown here:

```
pi@raspberrypi:~ $ mode2 -m -d /dev/lirc1
Using driver devinput on device /dev/lirc1
Trying device: /dev/lirc1
Using device: /dev/lirc1
code: 0xffffff00723d2800662300016c110000
code: 0x4f020001160200005602000115020000
code: 0x56020001790600005702000113020000
code: 0x57020001140200005902000111020000
code: 0x58020001120200005802000176060000
code: 0x59020001120200005802000113020000
Partial read 8 bytes on /dev/lirc1pi@raspberrypi:~ $
```

Figure 4: mode2 with erroneous output.

This diverted my attention towards other utilities provided by LIRC; irrecord, after it directed me to a database of remotes with their corresponding keycodes (4) to an unfruitful search, also proved to be erroneous because after recording KEY_POWER for the CASIO projector's remote, my keycode didn't match with my colleagues' keycodes for the same button! This threw me off to use ir-ctl which after reading the man pages revealed that it could be used to do both rx and tx but with raw IR codes! So, the lircd daemon was no use in this case since I didn't have to decode.

$ ir-ctl -1 - -receive=KEY_POWER.txt -d /dev/lirc1 was used to receive the raw codes of the

POWER button and save it in the KEY_POWER.txt file.

After this, testing of the rx part was done successfully. Before delving into the circuitry of the tx part, I was warned by my colleague Shivam to use a transistor to amplify the current supplied to the IR emitter such that its able to send the infrared signals to the projector with high-enough amplitude. Keeping this in mind the schematic of the circuit is given below:

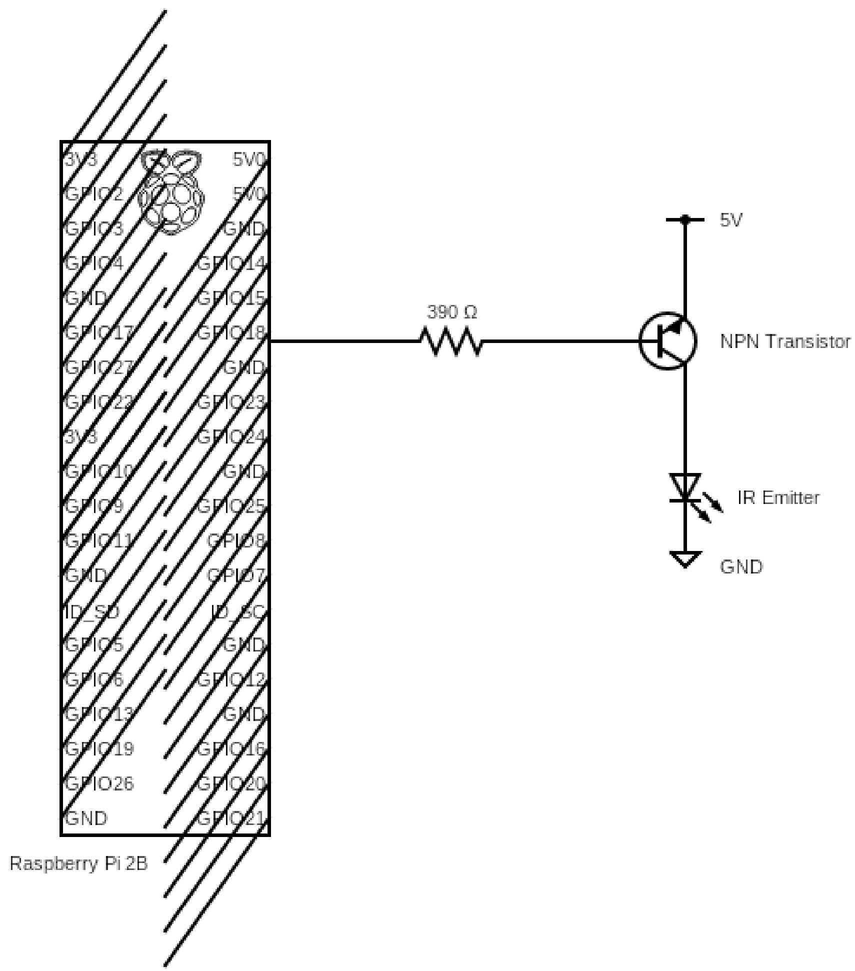


Figure 5: Circuit schematic (made using https://www.circuit-diagram.org/

$ ir-ctl - -send=KEY_POWER.txt -d /dev/lirc0 was used to emit the raw codes of the POWER button saved in the key_power.txt file. This completes my testing of tx part as well. Now, I just had to devise a solution to the question "When do I send the POWER signal to the projector?"

3.3 Mailbox

Unaware of the presence of Broadcom VideoCore VI processor on my Raspberry Pi Model 2B which handles the detection of HDMI instead of the ARM Cortex-A7 processor, I hypothesised that the HDMI event detection mechanism incorporated by my HP Pavilion 15 laptop should be the same in case of the Raspberry Pi. With this assumption, I carried out some unnecessary but enlightening experiments involving the ‘drm’ subsystem. It had a device in sysfs named under card0-HDMI-A-1 which had exposed attributes on the state of HDMI connection, device-specific information in EDID (Extended Display Identification Data) (5) format, etc (see figure below).

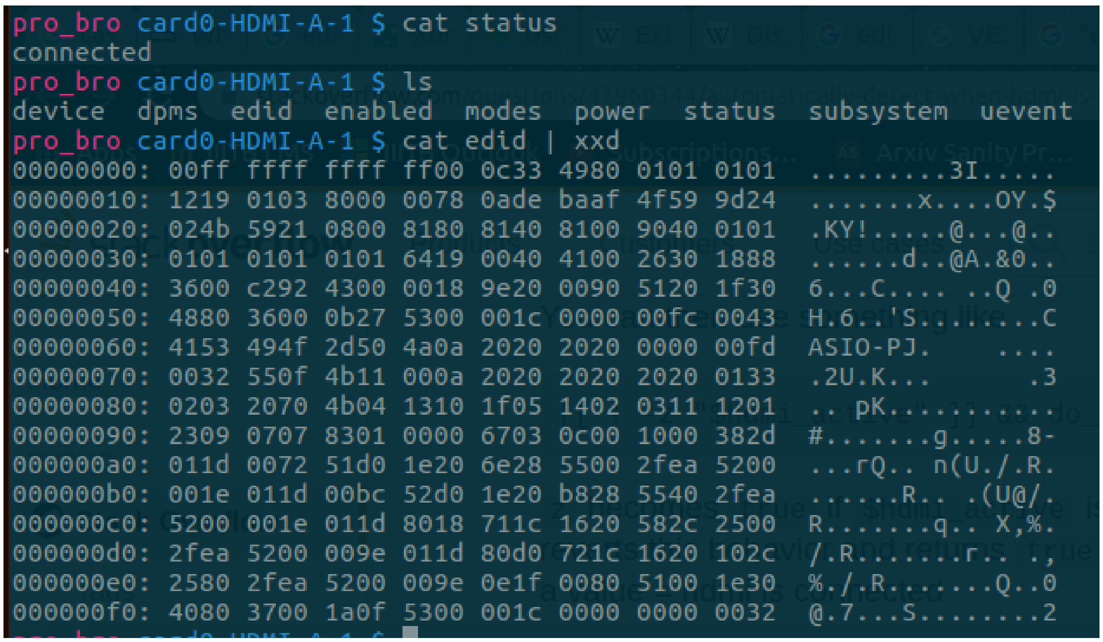


Figure 6: Attributes of device under drm subsystem.

This gave me an illusion on the complexity of the project in Raspberry Pi. This illusion was erased once I re-read the problem statement and discovered the absence of the ‘drm’ subsystem in RaspberryPi. But, borrowing ideas from the above experiment, I used the EDID format to detect the presence of an HDMI connect/disconnect event which I shall discuss in the report later.

Mentioned in the hints, I turned my attention towards using ‘tvservice’ and investigated how it uses Mailbox, an inter-processor communication mechanism between the ARM core and the Video-Core, to detect the state of HDMI connection when one uses the command-line utility: $ tvservice -s or $ tvservice -M. Upon reading the source code (6), I stumbled upon the different values (bitmask) the state can take. This proved to be useful in deciphering what the state code meant when one executed $ tvservice -s. Although, I wasn’t able to trace how ‘tvservice’ uses the Mailbox channels for the communication. Surfing through the ‘userland’ repository, I found the source code for ‘vcmailbox’ (7) utility. This had evident traces of how it uses the Mailbox1 (ARM to VC) to send request on channel 8 (search for MBOX_CHAN_PROPERTY) with property tags and how the response is received on Mailbox0 (VC to ARM) in the same buffer, which is in sync with the documentation (8). I even tried out a few examples by using the command-line utility $ /opt/vc/bin/vcmailbox [words] and tried to exercise the same code as this (9). This was too tedious when I tried to request EDID blocks with the property 'Get EDID Block' as mentioned here (10) as I got confused on request format. This is when my colleague Vijay suggested me to use Mailbox utility from kernel-modules (11)! This seemed like a more reasonable approach as this would be a kernel-space-based solution rather than a user-space one, where one would ideally just write a 'bash' script to continuously poll over tvservice's utility.

Tracing the source code (12) (13) (14), the whole communication interface between ARM and VC was much clearer. All I had to do now was write a miscellaneous device module which exposes an attribute called 'status' which, when read, sends a 'Get EDID Block' request to VC over the mailbox channel and with some further logic (discussed later) tells us if HDMI is connected or not. I used this approach (of exposing an attribute) for testing purposes and I soon realised how an 'uevent' mechanism would be much structured in this case.

3.4 uevents

On my colleague Mohana's recommendation, I decided to look through the source code for how one can generate 'uevents' from kernel modules (15). I devised a mechanism which generates a 'uevent' with CHANGE action and under a defined "myHDMI" subsystem whenever there is a change in state of HDMI connection; disconnected to connected and connected to disconnected. A corresponding .rules file was implemented which executes my previous findings on matching with my generated 'uevent'; sending a POWER infrared signal using ir-ctl.

3.5 hdmi_dev.c - Misc Device

Inspired by goonj.c and blinker.c, I wrote a misc_device module which sets up a timer to send a 'Get EDID Block' request (with workqueues because the requests are not atomic due to presence of locks (16)) to VC through a mailbox channel at a pre-defined rate and detects state change to generate an 'uevent' with some internal logic. The logic is that, when no HDMI device is connected, the reponse by VC should not contain any information to my request of 'Get EDID Block' and when some HDMI device is connected, I get some device-related data. I encountered a few errors involving devices which can send multiple blocks of data in the request but those were cleared after a thorough read of the EDID v1.3 (bytes 18 and 19 tell the EDID version) specification issued by VESA (17) (18) which said that the 127th byte tells us about the remaining extension blocks to come. Once I received all the EDID extensions correctly, I used edidparser to make sense of the received data which reflected the flawlessly execution of my module.

3.6 HPD in HDMI

The above approach of using a mailbox channel become obsolete when I discovered that GPIO 46 is connected to pin 19 (Hot Plug Detect) of the HDMI connector (19) in Raspberry Pi Model 2B. I even traced the lines in the schematic (page 2) (20) just to confirm! Upon learning more on about the detection process (21), it made a lot of sense for me to take this approach rather than the EDID one because it's much more "cleaner" and that pin must be solely meant to do HDMI detection. With this, I updated my hdmi_dev.c to hdmi_dev_v2.c which uses the get_gpio_value framework to read the level of GPIO 46. The other logic remains the same. Note: It's not necessary to use workqueues in this case although it made sense for me that a separate kernel-thread does the polling for me rather than the kernel module itself.

3.7 Modes in CASIO projectors

After numerous experiments, Mohana and I realised that the projector stays in STANDBY mode when the RED light is displayed. At this state, even if the HDMI connector is plugged in, it's not plausible to detect if it has been plugged in (we are assuming the power is not let through the connector). In response to this, I believe it's not possible to switch ON the projector when HDMI cable is plugged in; it must already be in state ON for it to detect the connection. This behaviour is not seen in cases of Monitors. I even explored other options apart from POWER signal like BLANK signal (puts the projector in low-power mode by switching off the display) but then I realised I was diverting away from the original problem statement.

4 Conclusion

The output matched the expectation in the case of HDMI disconnect event but not for the HDMI connect event because it does not seem possible to know if the HDMI is connected when the CASIO projector is OFF. Although, when the projector is ON and we plug in the HDMI connector, we can detect it. Below is the output:

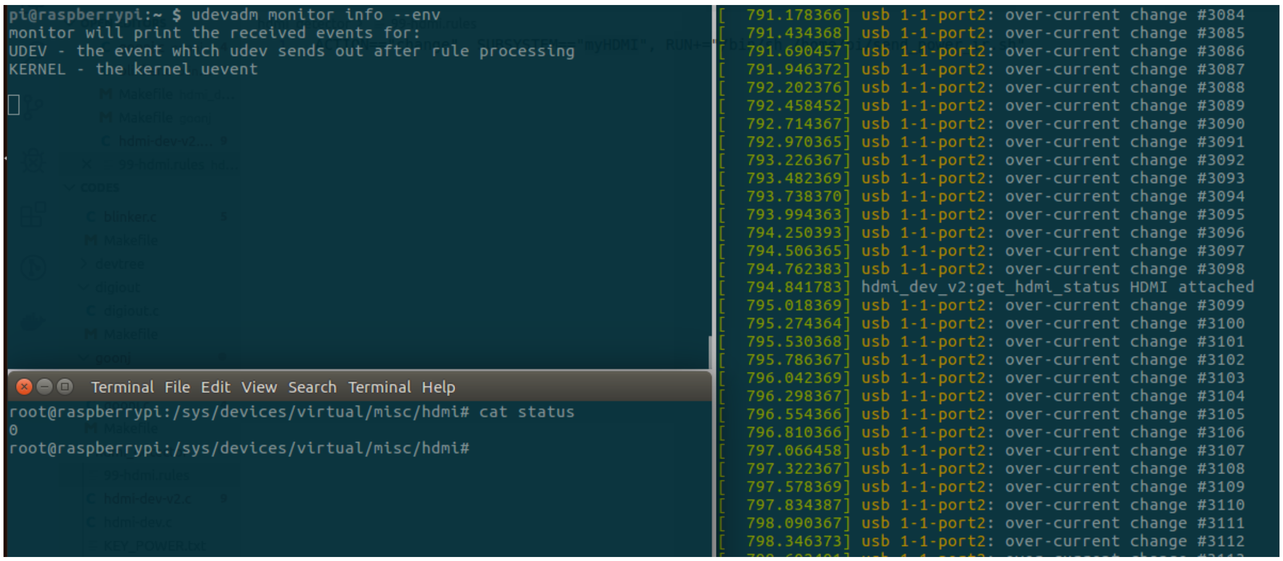


Figure 7: HDMI connect event; no uevent generated

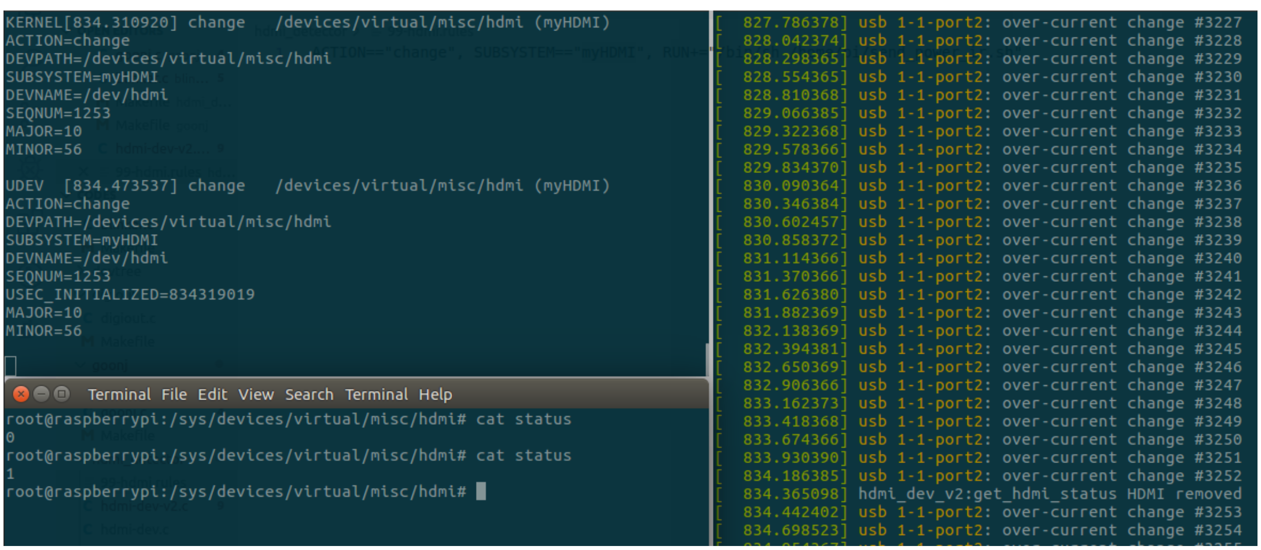


Figure 8: HDMI disconnect event; appropriate uevent generated

This project educated me on how to look through source code to interpret the author's intentions. It also enabled me to question my design choices through-out the process for example: kernel-space-based solution vs. user-space-based solution, misc_device vs. platform_device, the polling time, etc.

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