First S.Ha.R.K. Workshop
Pontedera
28th February – 4th March 2005

S.Ha.R.K. – Drivers & Interrupts

Mauro Marinoni [mauro.marinoni@unipv.it]

Robotic Lab
University of Pavia (Italy)

ARTIST2

FIRST
Flexible Integrated Real-Time Systems Technology

Objectives

- Drivers realization
  - Different approaches
  - S.Ha.R.K. evolution
- Present implementation in S.Ha.R.K.
  - Interrupt Server
  - Linux Compatibility Layer
  - Available drivers
- Work in progress
- Future Work

Drivers Implementation

- Different approaches to a new driver layer implementation:
  - Write it from scratch ;
  - Reuse low level calls code and rewrite the rest;
  - Reuse as much code as possible;
- Most of the recyclable code came from NOT Real-Time Operating Systems.

Comparison Terms

- The approach must be selected according to:
  - Requirements:
    - Predictability;
    - Reliability;
    - Stability;
    - Maintainability.
  - Team characteristics:
    - Dimension;
    - Knowledge;
    - Time.

Advantages & Drawbacks

- Importing pre-existent code:
  - Increase Reliability and Stability;
  - Require less technical knowledge and production time;
  - Decrease the amount of code that must be implemented.

Advantages & Drawbacks

- The code is not developed focusing on real-time issues then predictability is penalized.
- The imported code usually present a lot a features unusable on the new OS. This increase the execution time and the total code dimension.

"The only piece that can't break off is the one you don't mount"
Spitfire engineer

S.Ha.R.K. Drivers Evolution

- Most of the S.Ha.R.K. drivers system has been rewritten in the transition between versions 1.22 and 1.4.
- The point of view changed from an almost homemade implementation to an integration of drivers inherited from an external O.S.

S.Ha.R.K. Drivers Evolution

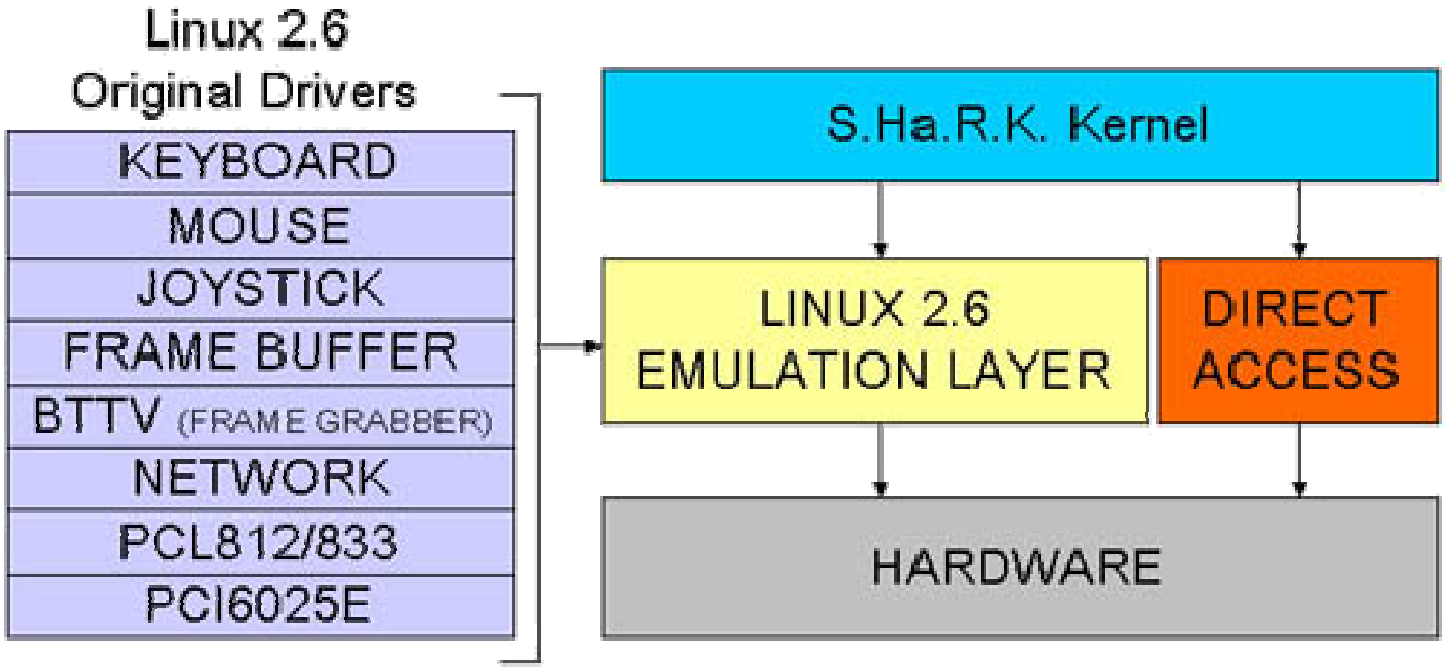
1.22 → **1.4**

- Drivers written from scratch;
- Almost full Real-Time implementation;
- Small drivers either in term of dimension or execution time;
- Few supported peripherals.

- Drivers inherited from Linux;
- Drivers rich of features;
- Small amount of code needs to be rewritten;
- Higher number of peripherals supported.

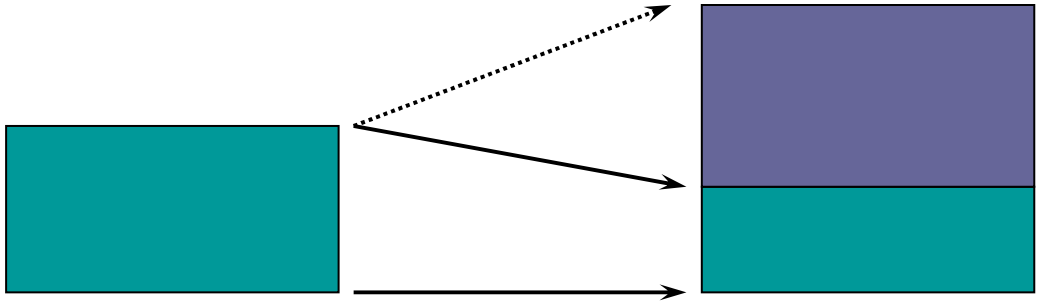
Modular Structure

- A modular approach was implemented to maintain backward compatibility and to allow full homemade drivers.



Good Things…

- The interesting part of the new approach is that porting a new driver is quicker and require a smaller amount of time and code.
- I.E. Porting the whole input layer (keyboard, mouse, joystick and PC speaker)
  - Requires one person for less than a week;
  - Code dimension grows from ? to 450Kb but only 70Kb need to be written.



… and Dark Shadows

- Linux ISRs are developed to work with disabled interrupts.
- Even if we can estimate a WCET for every ISR, it is not possible to guarantee how much utilization is stolen by ISR execution time during interrupt burst.

"One *layer* to rule them all, one *layer* to find them all, one *layer* to bring them all and in an *utilization estimation* bind them all."

The Interrupts Server

- Is composed basically of 4 elements:
  - A scheduling algorithm thought to manage only one non-preemptable task;
  - A not-preemptable task in charge of executing handlers.
  - A FIFO queue of interrupts waiting to be processed;
  - A list of couples (interrupt number, handler function);

The Interrupts Server

- When an interrupt is raised by a peripheral:
  - The S.Ha.R.K. handler puts it in the queue and makes a request for an activation of the task;
  - If the task presents enough capacity the ISR is executed, otherwise the handler waits for the next recharge.
  - When the task ends an ISR, if some capacity is left, it looks for a new job in the queue.

The Interrupts Server

- With this approach we are able to:
  - Protect the ISR from Linux code;
  - Guarantee a maximum value for the utilization code.

"*A beginning is a very delicate time*"
Frank Herbert, Dune

Drivers from Linux 2.6

- Input
  - Standard keyboard (Linux 2.6 INPUT/KEYBOARD driver)
  - Standard PS/2 mouse (Linux 2.6 INPUT/MOUSE driver)
  - Analog and digital joystick (Linux 2.6 INPUT/GAMEPORT driver)
- Graphics
  - VESA 2.0
  - MATROX, NVIDIA, ATI (only the Linux 2.6 supported) (Linux 2.6 FRAMEBUFFER driver)
- Frame Grabbers
  - BookTree chipset BT848/BT878 (Linux 2.6 BTTV driver)
- Voltage/Frequency scalable CPU (Linux 2.6 CPUFREQ driver)

Drivers from S.Ha.R.K 1.22

- I/O PORTS
  - Standard RS232 and Parallel port
- I/O Cards
  - PCI6025E, PCL812, PCL833 (Shark 1.22 drivers patched for Linux 2.6 emulation layer)
- Network (only UDP support)
  - RTL8139, 3C90X, 3C509, PRO100 (Old Linux drivers patched to work with Linux 2.6 emulation layer)

Linux Compatibility Layer:

- Works as a filter between the S.Ha.R.K. kernel and Linux drivers;
- Remaps Linux system call to S.Ha.R.K. ones;
- Initialize Linux infrastructures like busses, classes ad devices;
- Is in charge of maintaining data structures needed by drivers.

LinuxComp - Example

- A Linux driver calls the **`request_irq`** function:
  - Parameters are stored in a structure;
  - The **`handler_set`** function is executed with 2 parameters:
    - Interrupt number;
    - **`linux_intr`** function, from LinuxComp, as handler;
  - Return values and error codes are translated and sent back to the caller;

LinuxComp – Ex(2) (The Revenge)

- When an interrupt arises the S.Ha.R.K. kernel executes the **`linux_intr`** function with the interrupt number as the only parameter;
- The **`linux_intr`** function gets data previously sent by **`request_irq`** and runs the correct handler with related parameters;

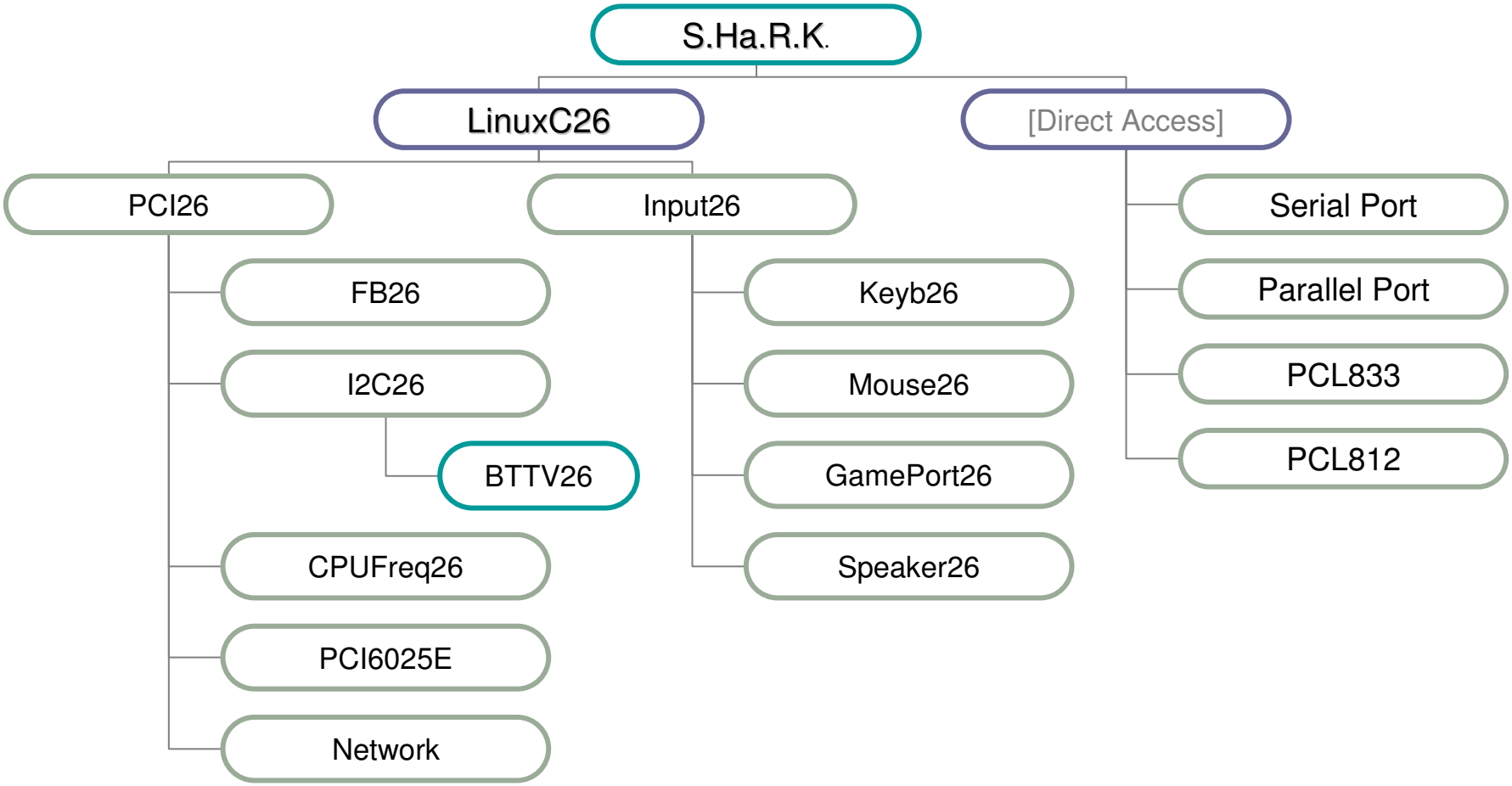
Drivers Dependencies

- S.Ha.R.K. 1.4 DOESN'T already manage all dependencies;
- For a correct application execution an order must be followed in driver initialization;
- Even when the system will exploit automatically drivers dependencies, a full list of init functions calls leads to a better understanding of the application.

Drivers Dependencies - Ex

- The network layer needs the PCI bus drivers to probe and to initialize correctly NIC boards;
- If the PCI driver is not present when the network driver tries to scan for cards the user receives a "`No network card found`" message.

LinuxC26 Dependencies Tree



Drivers Functions

- Each driver presents:
  - One initialization function;
  - One closing function (not all of them);
  - Some control functions;
  - Some I/O functions.

LinuxC26 and PCI26

- LinuxC26 is the core of the compatibility layer. It presents only the initialization function: `LinuxC26_init()`.
- The PCI26 driver needs to be initialized with the `PCI26_init()` function which fills all structures for the PCI bus; these structures are needed by some Linux drivers.

Input26:

- Initializes the Input layer which works as a bridge between low level drivers (i8042,atkbd, ns558,…) and high level handlers (keyboard, mouse, joystick, …);
- Presents only 2 functions:
  - INPUT26_init() – Which fills all structures and runs some chipset probes;
  - INPUT26_close() – That frees structures, IRQ, etc.

Keyboard26

- The keyboard driver activation is managed through 5 functions:
  - **`KEYB26_init`** – Which performs Hw/Sw initialization;
  - **`KEYB26_close`** – Which stops the software and frees hardware resources;
  - **`KEYB26_installed`** – That returns if the driver is installed;
  - **`KEYB26_enable`**, **`KEYB26_disable`** – Are in charge of swap between accept and drop the policy about data coming from the keyboard;

Keyboard26 - Acquisition

- The application can recover an ASCII code related with a pressed key with the **`keyb_getch`** function;
- If the buffer is empty the function waits for a new key or returns 0 depending on the parameter **`wait`** given by the application.

Keyboard26 - KeyEvent

- It is a structure containing the following fields for each event related with keys:
  - The ASCII code;
  - The scan code;
  - The status: the key is pressed, repeated or released;
  - The flags encoding: it says if ALT, SHIFT or CTRL buttons are pressed;

Keyboard26 - KeyEvent

- It can be used in 2 modes:
  - Directly with the keyb_getcode function which returns the first unprocessed event in the FIFO queue;
  - Linking an handler to a predefined KeyEvent using the keyb_hook function: when a new event arrives it is compared with the hooks list and, if a match is found, the related handler is executed.

Mouse26

- The mouse driver presents a structure analogous to the keyboard one:
  - Initialization: **`MOUSE26_init`**, **`MOUSE26_close`**, **`MOUSE26_installed`**, etc.
  - Interaction with applications: **`mouse_getposition`**, **`mouse_hook`**, etc.
- There is also a set of functions for the cursor visualization either in text or graphics:

`mouse_on`, **`mouse_off`**, **`mouse_txtcursor`**, **`mouse_grxcursor`**, **`mouse_textshape`**, **`mouse_grxshape`**.

Gameport26

- The gameport driver works ONLY with hardware which presents a "*SoundBlaster Gameport Emulation*" on 201H port.
- The interface is composes only by:
  - Init functions: `JOY26_init`, etc;
  - Activity functions: `joy_enable`, `joy_disable`;
  - Pointer position functions: `joy_setstatus`, `joy_getstatus`.

Speaker26

- Least but not last, the speaker driver allows to emit a sound through the PC speaker.
- Other than usual function for initialization we can see 2 functions:
  - **`speaker_sound`** – Which emits a beep at the required function for a chosen period or in a never ending loop;
  - **`speaker_mute`** – That resets the speaker output.
- Was sometimes useful for debug purposes instead of text, graphic or network debug.

FrameBuffer26

- The driver allows to work with graphic primitives on *16 bpp SVGA* graphics modes.
- The correct order for initialization is:
  - Init hardware and internal structures with **`FB26_init`**;
  - Open the frame buffer using the **`FB26_open`** function;
  - Connect the drawing library through the **`FB26_use_grx`** call;
  - Set the required graphic mode with **`FB26_setmode`**.

FrameBuffer26

- Drawing functions are inherited from the old (S.Ha.R.K. 1.22) Grx library, maintaining the same syntax;
- Modes are in the form "**`widthxheight-bpp`**" (Ex. "**`640x480-16`**"). It can sometime be useful to fix the refresh rate manually (Ex. "**`640x480-16@60`**").

FrameGrabber

- It is divided into 2 parts:
  - The low level driver (BTTV) which manages acquisition cards based on BookTree chips;
  - The high level driver (VIDEODEV) that controls video peripherals.
- Adding another frame grabber consists in porting ONLY the new low level driver.

FrameGrabber – BTTV

- It works as a filter between the videodev interface and acquisition boards based on BookTree BT8x8 chips.
- It supplies only 2 functions:
  - BTTV26_init – Which initializes the acquisition board and all internal structures;
  - BTTV26_close – That shutdowns the low level driver.

FrameGrabber – VideoDev

- This layer allows an easy and uniform interaction between the application and low level drivers;
  - The function **`VIDEODEV26_open`** opens the communication with the device through the low level driver;
  - Every other interaction is performed using the **`VIDEODEV26_ioctl`** function which sends commands to the device.

FrameGrabber – VideoDev

- The list of supported commands is the same of Linux 2.6 VideoDev with the exception of VIDIOSYNC which has been totally rewritten. It accepts a task PID as an argument; this is executed when a new frame is ready.
- Attention: The task MUST be an aperiodic one.

FrameGrabber – Example$_1$

```
/* Init videodev driver */
VIDEODEV26_open(FRAME_GRABBER_NUMBER);

/* Select the input channel */
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCGCHAN,(unsigned long)&chan);
chan.channel = channel;
chan.type = VIDEO_VC_TUNER;
chan.norm = VIDEO_TYPE_CAMERA;
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSCHAN,(unsigned long)&chan);

/* Select palette and depth */
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCGPICT,(unsigned long)&vpic);
vpic.palette = VIDEO_PALETTE_RGB24;
vpic.depth = 24;
vpic.brightness = 35000;
vpic.hue = 32000;
vpic.contrast = 32000;
vpic.colour = 32000;
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSPICT,(unsigned long)&vpic);
```

FrameGrabber – Example$_2$

```
/* Enable the tuner */
tuner.tuner = 0;
tuner.mode = VIDEO_MODE_PAL;
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSTUNER,(unsigned long)&tuner);

/* Set window dimensions */
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCGWIN,(unsigned long)&win);
win.x = 0;
win.y = 0;
win.width = FG_W;
win.height = FG_H;
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSWIN,(unsigned long)&win);

/* Set the buffer */
res = VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSFBUF,(unsigned long)(fbuf));

/* IMPORTANT: Set the aperiodic elaboration task */
VIDEODEV26_ioctl(FRAME_GRABBER_NUMBER,VIDIOCSYNC,(unsigned long)(task_PID));
```

CPUFreq26

- The driver probes the system for processor information and supplies an API interface for frequency scaling, if supported from CPU.
- A set of functions for getting scaling information is implemented: min/max frequency, current frequency, all supported frequencies, latency.
- A function permits to change the current frequency.

Network

- The driver is inherited from previous versions of S.Ha.R.K. and mixes homemade code with Linux 2.0 code;
- Support only a small set of NIC cards;
- Supplies IP and UDP protocols interfaces;

Network – I.E. Init

- To initialize the network subsystem the procedure is:

```
struct net_model m = net_base;

/* Set a task for TX mutual exclusion */
net_setmode(m, TXTASK);
/* Use UDP/IP stack */
net_setudpip(m, localipaddr, "255.255.255.255");
/* Start NetLib */
if (net_init(&m)!=1)
      exit(1);
```

Network – I.E. Receive

- To receive data via UDP:

```
UDP_ADDR from, local;
int s, n;

/* Connect on local port 100 */
Local.s_port = 100;
s = udp_bind(&local, NULL);

/* Receive the packet (block until it arrives) */
n = udp_recvfrom(s, n, &from);
```

Network – I.E. Send (1)

- To send data using UDP:

```
UDP_ADDR to, local;
IP_ADDR bindlist[5];
int s;

/* Set the source port */
ip_str2addr(localipaddr,&(local.s_addr));
local.s_port = 101;
```

Network – I.E. Send (2)

```
/* Bind */
ip_str2addr(remoteipaddr, &(bindlist[0]));
memset(&(bindlist[1]), 0, sizeof(IP_ADDR));
s = udp_bind(&local, NULL);

ip_str2addr(remoteipaddr, &(to.s_addr));
to.s_port = 100;

/* Send Packet */
udp_sendto(s, buff, strlen(buff), &to);
```

Put everything on the road…

- Usually all init and close functions resides in the initialization file.
- The standard implementation is composed of:
  - One boot function which makes all requested drivers start;
  - One function starts when the system enters the `SHUTDOWN` runlevel;
  - One aperiodic task, started by the previous function, that executes all closing actions.

How to port a driver?

- There is not a standard procedure to port a Linux driver in S.Ha.R.K. because everything depends on:
  - Underlying hardware;
  - Previously ported drivers;
  - Requested resources.
- For example:
  - USB keyboard and mouse use the input layer and don't need a user API;
  - Serial mouse searches the `tty` interface and it is not actually ported because the `tty` layer is big and is not needed by any other driver;

How to port a driver?

- Some useful tips commonly applied till now:
  - To copy Linux files in a new directory under drivers;
  - To create a new makefile (*see input/bttv/cpu/fb*);
  - To create an include directory for files needed by S.Ha.R.K. applications;
  - Sometimes to create a new directory for S.Ha.R.K. code is useful.

How to port a driver?

- Pay attention that:
  - No device filesystem is implemented: you need to create some API functions in order to obtain communication between driver and application;
  - No up/down function remapping is done by now: you need to comment them out.

I want MY driver!

- If, for some particular real-time constraints, a full real-time driver is required, then:
  - Write it from scratch;
  - Put it side by side with Linux-ported drivers;
  - Let then run together;

"In a world of fugitives, the person taking the opposite direction will appear to run away"

T.S. Elliot

Latest News

- Almost ready:
  - New interrupt management implementation: it is possible to choose if using IntDrive or not for a single application;
  - Complete drivers dependencies check: autoload a driver if requested during the boot of another driver;
  - Integration of features requested from version 1.4 release.

Drivers on the way

- In various different developing states are:
  - USB26 (needs debug and documentation):
    - Pwc webcams;
    - Gps modules;
    - Input (keyboard, mouse, joystick/gamepad);
    - Serial adapter;
  - Network26 (starting blocks):
    - Which part ?!?

Next Generation

- Drivers discussed but not assigned:
  - Comedi;
  - Device Filesystem;
  - L4 integration;
  - ...

Mauro Marinoni [mauro.marinoni@unipv.it]

Robotic Lab - University of Pavia (Italy)

S.Ha.R.K. – Drivers & Interrupts

- Site: http://shark.sssup.it
- Forum: http://feanor.sssup.it/retis-projects
- Bugzilla: http://lancelot.sssup.it/bugzilla

- Retis: http://retis.sssup.it
- RoboLab: http://robot.unipv.it

ARTIST2

FIRST
Flexible Integrated Real-Time Systems Technology