DFRobot project



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# Introduction

This project was started beginning 2015 to get familiar and (even more) enthousiastic about embedded systems, embedded Linux, Robotics. Its fits very well the curriculum of the Fontys FHICT Technology study. Topics addressed are:

* Embedded systems
* Embedded Linux
* Networking
* Web server, webpage development
* Video streaming over internet
* ROS
* Programming C, C++, Python, Bash

To get started the following hardware is used:

* DFRobot 4WD Arduino Mobile Platform
* Raspberry Pi Model B+ Computer Board, replaced by Raspberry Pi 2 Model B on 24/07/2015.
* Raspberry Pi Camera Module
* DFRduino Uno USB Microcontroller V2.0
* DFRobot Arduino Compatible Motor Shield (2A)
* Lynxmotion Pan and Tilt Kit / Aluminium
* Netgear Wireless N Adapter 150 Mbps (USB) (WNA1100-100PES)
* GY-271 module with HMC5883L 3-Axis Digital Compass
* 4x HC-SR04 ultrasonic sensor

The project will never be ‘finished’ and is perfect for keeping up to date with the latest technologies. At the moment the following phases are foreseen:

**Phase one: feasibility**

In this phase I want to investigate the areas which I see as high risk and which are crucial for success of the project. Better to encounter problems in these areas right away than later in the project.

* Spike to see if it was possible to have low latency (< 2 sec) streaming video from the Raspberry Pi to a standard web browser (no plugins). This is not trivial and a lot of discussions can be found in forums.
* Spike to see how to control the Pi Camera and the Pi I/O pins from a standard web browser. Different techniques can be used and it would be good to use the right one for this project.

**Phase two: Basic system up and running**

* Robot platform controlled from a standard web browser containing streaming video. Status information will also be available.
* Next to that a charging station will be built and it should be possible to manually drive to the driving station and attach.

**Phase three: Adding more features / intelligence**

In this phase I want to add intelligence and features.

* Adding sensors like for measuring distance, temperature etc…
* Let the robot drive independently every hour and upload the video to Google Drive.
* Let the robot detect motion and upload the video to Google Drive.
* Let the robot automatically find and attach to its charging station when needed.
* Adding servo’s for grabbing.
* Let the robot create a map of the environment so that it can orientate itself and one can give commands like: go to room X position Y. This is where ROS comes in.
* Automatic uploading of video and log files to Google Drive.
* Let the robot be on WhatsApp / Telegram.
* Add speech recognition.
* Add speech output.
* Let the robot act as a personal assistant: let it read the news, play music, set an alarm, answer questions etc… .
* FPV (First Person View) mode!
* Experimental: connect the robot to game engine Unity through a socket and let Unity control the robot.

# Raspberry Pi configuration

## SD card configuration and boot process

On the SD card there are two partitions:

* Boot partition (FAT32 formatted). This partition contains:
  + The firmware which will load various settings and the kernel.
  + Raspbian kernel image (kernel7.img). The kernel contains several important parts: process management, memory management, hardware device drivers, filesystem drivers, network management, and various other bits and pieces.
  + The second-stage bootloader and the third-stage bootloader. The first-stage bootloader is located in SoC ROM. In sequence:
    - The first-stage bootloader mounts the boot FAT32 partition.
    - The second-stage bootloader (bootcode.bin) loads the firmware (start.elf) in the GPU for execution. The CPU is not available yet at this stage.
    - The third-stage bootloader (start.elf) is the ‘firmware’ of the GPU. It will load the settings in config.txt (like arm\_freq, gpu\_freq, h264\_freq …). Finally it loads kernel7.img in the RAM and resets the ARM CPU so the ARM CPU will start executing kernel7.img which will further load the operating system.
* Linux partition (EXT4 formatted). This partition contains the other operating system parts and the packages.

## Raspbian and packages

On the Raspberry Pi Raspbian is installed. Run ‘sudo apt-get update’ and ‘sudo apt-get upgrade’ to upgrade all installed packages including kernel and firmware. Note that also the firmware is upgraded this way to the last stable version. **Do not use rpi-update to update the firmware.** rpi-update will also update the firmware, but then to the very latest unverified version. This is not necessary and unreliable!  
The file ‘/etc/apt/sources.list’ contains the url to the package repository for the OS release (e.g. Wheezy) so the packages will be for that OS release. For upgrading to a new major OS release, e.g. from Raspbian Wheezy to Raspbian Jessie, ‘/etc/apt/sources.list’ has to be modified and an upgrade path has to be followed.

## Backing up the SD card image of the Raspberry Pi

Before creating an image it is wise to clean things up, like removing downloaded packages with sudo apt-get clean.

To create an image of the Pi SD card the dd command can be used. Put the SD card in the Mac and identify the 16 GB SD card disk with ‘diskutil list’. The Identifier will be something like ‘disk2’. **Please check this as it varies between OS X versions!** Then in the dd command one can use /dev/disk2 for the device or for higher speed raw disk /dev/rdisk2 which is ok when using the dd command.

sudo dd if=/dev/rdisk2 of=/Users/reneb/Git/GitHub/DFRobot\_SDcardBackup\_TooLargeForGithub/SDcardBackup20170730.img bs=1m

or to save space:

sudo dd if=/dev/rdisk2 bs=1m | gzip > /Users/reneb/Git/GitHub/DFRobot\_SDcardBackup\_TooLargeForGithub/SDcardBackup20170730.gz

This will create an image you can use to create a new SD card. This image can be restored on an SD card using again the dd command:  
sudo dd bs=1m if=/Users/reneb/Git/GitHub/DFRobot\_SDcardBackup\_TooLargeForGithub/SDcardBackup20170730.img of=/dev/rdisk2

To allow overwriting the disk you have first to unmount /dev/disk2 with: sudo diskutil unmountDisk /dev/disk2 otherwise the resource will be busy. Note that unmounting a disk is not the same as ejecting it from the file explorer.  
When using an 8 GB SD card it might be needed to expand the root file system to make sure the complete memory card is used. This means that the Linux partition of the SD card will be expanded. This can be done using ‘sudo raspi-config’ and selecting the ‘Expand Filesystem’ option. The data will remain. However, this operation cannot be undone and has the risk that the partition will not fit anymore on another SD card of a ‘similar’ size! This because SD card sizes can differ per manufacturer. So it is wise to do the filesystem expansion on the smallest SD card so the image can be copied back and forth without problems to other SD cards.

After having smaller partition sizes which will fit on ‘similar’ sized SD cards it can still be that the total image size will be larger than the size of another SD card. This because the image file created with the dd command for /dev/disk2 is the image for the complete SD card being partition table + partitions + empty space. So the dd restore command can still give an error like ‘short write on character device, Input/output error’. This is not a problem because the partitions will still fit.  
Instead of using dd to backup and restore images it is possible to use 'rsync -avx oldFilesystem newFilesystem' which does a file level copy instead of a complete partition.

## Mounting the Raspberry Pi SD card in Ubuntu using VMware Fusion or VirtualBox

When the Raspberry Pi SD card is corrupt and connection to the DFRobot is not possible anymore, it might be possible to fix it by changing a file on the SD card. Then it is useful to be able to write Raspbian files when inserting the SD card in the Mac. Because the Raspbian Linux partition cannot be read normally under OS X (except with Fuse for OS X), we make use of Ubuntu and WMware Fusion (VirtualBox did not seem to work here).  
On the Mac, start Ubuntu in VMware Fusion. Insert the SD card in the Mac and eject it under OS X. In VMware Fusion: Ubuntu 64 bit -> Virtual Machine -> USB & Bluetooth -> Connect Apple Internal Memory Card Reader. In Ubuntu the memory card should appear. In the file browser it is read only so we need to mount it to be able to acces it in terminal. Open terminal and list the devices with ‘sudo fdisk –l’. There the name of the Linux partition of the SD card can be seen, e.g. ‘/dev/sdb2’. This device can be mounted with ‘sudo mkdir /sdcard’ and then ‘sudo mount /dev/sdb2 /sdcard’. Then the Linux partition can be accessed at ‘/sdcard’ from the terminal. ‘sudo’ can be used to write files if needed. Note that some files cannot be seen as standard user as they are readable only by the root. **Unfortunately the above only works on Macs with an SD card slot and not on newer Macs with an SDXC (SD extended capacity) card slot, because the latter does not use the USB bus**.

The easiest solution to the above is solution is to use an external USB microSD card reader. Then also VirtualBox can be used!

## Connecting the Raspberry Pi to the MacBook via the ethernet cable

We want to connect the Pi to the MacBook through the Ethernet cable so we can control the Pi with the keyboard / screen of the MacBook and also provide internet access to the Pi. The latter is done by enabling internet sharing on the MacBook.

* First configure the MacBook Ethernet network settings to static IP 192.168.2.1. It must be this address because this is the fixed IP address which the OS X Mavericks uses when enabling internet sharing. The address 192.168.2.1 address means that the Pi must have a static address in the same subnet, e.g. 192.168.2.2. This is accomplished by setting this in **/etc/network/interfaces**. Also the gateway of the Pi has to be set there and this must be the IP of the MacBook: IP 192.168.2.1.
* Internet sharing from MacBook:  
  When enabling internet sharing on the MacBook the MacBook apparently always uses 192.168.2.1. This is on a different subnet then the Wifi, so the MacBook acts as a router.
* A reboot might be needed before internet sharing is really working. Still the setup seems not very reliable.

## Network configuration in /etc/network/interfaces

For the wlan0 interface (Wifi) DHCP is used. Using DHCP is convenient so the Pi also can operate in other networks, like in a phone’s tethering network! A fixed DHCP address can be supplied by the router, which is convenient so the Pi always has the same IP address which is also needed for port forwarding. This means that the router must assign a static DHCP IP address (192.168.1.42) to the Pi (using its MAC address).  
Below note that for the ethernet interface no DHCP is used but static IP address settings which is convenient because the Ethernet DHCP service on the Mac apparently cannot supply a static DHCP IP address, so finding out the Pi’s IP address is difficult then.

auto lo

iface lo inet loopback

iface eth0 inet static

address 192.168.2.2

netmask 255.255.255.0

gateway 192.168.2.1

allow-hotplug wlan0

iface wlan0 inet manual

wpa-roam /etc/wpa\_supplicant/wpa\_supplicant.conf

iface default inet dhcp

## Wifi configuration in /etc/wpa\_supplicant/wpa\_supplicant.conf

Below note the network section for the tethering network of a phone!

ctrl\_interface=DIR=/var/run/wpa\_supplicant GROUP=netdev

update\_config=1

network={

ssid="wifiwifiwifi"

psk="fill in password here"

# Protocol type can be: RSN (for WP2) and WPA (for WPA1)

proto=RSN

# Key management type can be: WPA-PSK or WPA-EAP (Pre-Shared or Enterprise)

key\_mgmt=WPA-PSK

# Pairwise can be CCMP or TKIP (for WPA2 or WPA1)

pairwise=CCMP

#Authorization option should be OPEN for both WPA1/WPA2 (in less commonly used $

auth\_alg=OPEN

}

network={

ssid="AndroidAP"

psk="AndroidAP"

# Protocol type can be: RSN (for WP2) and WPA (for WPA1)

proto=RSN

# Key management type can be: WPA-PSK or WPA-EAP (Pre-Shared or Enterprise)

key\_mgmt=WPA-PSK

# Pairwise can be CCMP or TKIP (for WPA2 or WPA1)

pairwise=CCMP

#Authorization option should be OPEN for both WPA1/WPA2 (in less commonly used $

auth\_alg=OPEN

}

Testing internet speed from command line:  
wget -O /dev/null http://speedtest.wdc01.softlayer.com/downloads/test10.zip

## Connecting the Raspberry Pi to the wireless network (no Ethernet cable)

* Configure the file /etc/network/interfaces and the /etc/wpa\_supplicant/wpa\_supplicant.conf like above.
* The Pi will get an IP address assigned by DHCP: 192.168.1.42.

## Logging into the Raspberry Pi with SSH and with VNC

* Connect to Pi via SSH: ssh [pi@192.168.1.42](mailto:pi@192.168.1.42), password ‘raspberry’.
* Install VNC server on Pi and VNC client on MacBook.
* Start up VNC server on Pi with: ‘vncserver :1’.
* Start up VNC client on MacBook and connect to 192.168.1.42, password ‘raspberry’.

## Logging into the Raspberry Pi with X11 forwarding with SSH

* Connect to Pi via SSH: ssh –Y [pi@192.168.1.42](mailto:pi@192.168.1.42), password ‘raspberry’. Note the ‘-Y’ which enables trusted X11 forwarding. ‘–X’ can also be used but then it will timeout after the default 20 minutes ‘ForwardX11Timeout’ timeout of untrusted connections.
* Install XQuartz on MacBook and set X11 output preferences to ‘Full-screen mode’.
* Start ‘/etc/X11/Xsession’ on the Pi. This will automatically launch XQuartz on the Mac showing the X11 window.
* With cmd-option A one can go back from full screen Pi to the Mac.

## Raspberry Pi file sharing

At http://4dc5.com/2012/06/12/setting-up-vnc-on-raspberry-pi-for-mac-access/ it is described how to set up file sharing. Netatalk is installed which is an open source AFP (Apple Filing Protocol) file server. Then Avahi is installed which is a zero configuration service discovery protocol. The file ‘/etc/avahi/services/afpd.service’ is created with the avahi settings (a.o. TCP/IP port 548 is specified). Avahi is then started as a deamon which will start automatically after each reboot.

In /etc/netatalk/AppleVolumes.default at the end there is:

~/ "Home Directory"

which is the default folder to share. There you can add an extra path to share like:

/etc "/etc"

/lib “/lib”

Then on the Mac, in finder, press cmd-K (connect to server) and enter the Pi IP address and password. Then the Pi shared folder shows up in the shared section in the Finder sidebar.  
When writing to a Pi folder like ‘/etc’ from the Mac the permission is denied. This is because the user ‘pi’ is not the owner or member of the group of that folder (root is) and the permission is on 755. When writing to ‘/etc’ is needed, on the Pi do: ‘sudo chmod 777 /etc’.

After writing put back permission to 755 with ‘sudo chmod 755 /etc’.

## Raspberry Pi camera module, MJPEG streaming

For MJPEG streaming mjpg-streamer is installed following <http://petrkout.com/electronics/low-latency-0-4-s-video-streaming-from-raspberry-pi-mjpeg-streamer-opencv/> which is a mjpg-streamer fork of Liam Jackson. The installation directory chosen is /opt/mjpeg-streamer instead of /usr/src/mjpeg-streamer. When building this mjpeg-streamer, first remove the add\_subdirectory(plugins/input\_opencv) in CMakeLists.txt as this is not working with openCV 2.4. For easy calling of mjpeg-streamer, copy the built input\_uvc.so and output\_http.so plugins to the top directory.  
For MJPEG streaming also the UV4L (User space Video For Linux) framework from Luca Risolia can be used. However, the MJPEG stream generated by this framework has problems when trying to read it with OpenCV (premature ending of jpg frames). The quality of this framework is the same as the quality of mjpeg\_streamer.

To start the camera and MJPEG stream:

LD\_LIBRARY\_PATH=/opt/mjpg-streamer/mjpg-streamer-experimental/ /opt/mjpg-streamer/mjpg-streamer-experimental/mjpg\_streamer -i "input\_raspicam.so -vf -hf -fps 10 -q 10 -x 800 -y 600" -o "output\_http.so -p 44445 -w /opt/mjpg-streamer/mjpg-streamer-experimental/www" > /dev/null 2>&1.

The stream can be viewed via the MJPG-Streamer web page at 192.168.1.42:44445 or directly at 192.168.1.42:44445/stream\_simple.html.

To stop the stream use:

‘killall mjpg\_streamer > /dev/null 2>&1’

Stopping the stream can also be done by installing uv4l-raspicam-extras and using ‘/usr/sbin/service uv4l\_raspicam stop’ but this seems not to be reliable.

The stdout generated by the Bash CGI script is sent back to the browser, to capture all stdout output which must not be returned to the html.

This can be done using '> /dev/null 2>&1' or writing to a logfile.

## Local record of video stream in H264

Recording a H264 video stream can be done using the ‘raspivid’ command. For example:

‘raspivid -o /home/pi/DFRobotUploads/dfrobot\_pivid.h264 -w 1280 -h 720 -vf -hf -t 60000 > /dev/null 2>&1 &’ to record a one minute 1280x720 video with a vertical and horizontally flipped image. This is raw H264 video which cannot be played by most media players. To enable the ‘www-data’ user to run this command the ‘DFRobotUploads’ folder must have ‘777’ permission as the folder where the log files are written.

To wrap it into a MP4 container format install gpac with ‘sudo apt-get install -y gpac’. After this the video can be converted with: ‘MP4Box -fps 30 -new -add /home/pi/DFRobotUploads/dfrobot\_pivid.h264 /home/pi/DFRobotUploads/dfrobot\_pivid.mp4 > /dev/null 2>&1’.

raspivid can be stopped using ‘killall raspivid’.

To enable different users like ‘pi’ and ‘www-data’ to both recreate these video files the permission has to be changed to ‘666’ once.

Recording the local video stream with ‘raspivid’ cannot be done together with streaming the MJPEG video with UV4L.

## Capturing the http MJPEG stream while driving

Capturing the http MJPEG stream and convert it to a viewable format can be done by using VLC. At the moment VLC on the Raspberry does not seem to be able to transcode, but capturing and encapsulating it in ‘MPEG TS’ format works.

This can be done with:

‘cvlc http://localhost:44445/stream\_simple.html --sout '#standard{mux=ts,dst=/home/pi/DFRobotUploads/dfrobot\_pivid\_man.mp4,access=file}' --run-time=60 vlc://quit > /dev/null 2>&1 &’.

The ‘--run-time=60 vlc://quit’ part is to let VLC stop recording after 60 seconds, in case the driver forgets to stop it when finished.

This format is not recognized by Google Drive but it can be played by VLC.

As soon as transcoding works use:

‘#transcode{vcodec=h264}:standard{mux=ts,dst=/home/pi/DFRobotUploads/dfrobot\_pivid\_man.mp4,access=file}' --run-time=60 vlc://quit > /dev/null 2>&1 &’.

This format is recognized by Google Drive.

The capturing can be stopped using ‘killall vlc > /dev/null 2>&1’.

Just capturing and storing the mjpeg stream to a file can be done using curl:

‘curl -s -o /home/pi/DFRobotUploads/dfrobot\_pivid\_man.mjpeg http://localhost:44445/stream\_simple.html > /dev/null 2>&1 &’.  
However this file cannot be played by a standard media player.

## Raspberry Pi microphone audio streaming

To stream the microphone audio signal to the DFRobot webpage the following command is used:

cvlc alsa://hw:1,0 --sout '#transcode{acodec= s16le,channels=1,samplerate=16000}:standard{access=http,mux=ogg,dst=:44446}'

On the html webpage the following html5 audio element is used:

<div style="position: absolute; top: 700px; left: 5px;">

<audio controls>

<source id="audioSrc" src="http://<ip addr>:44446/" type="audio/ogg">

</audio>

</div>

The above ‘http://<ip addr>:44446/’ will be filled in dynamically by JavaScript.

## Uploading files from the Raspberry Pi to Google Drive

To upload files from the Raspberry to Google Drive ‘gdrive’ is used, see <http://www.webupd8.org/2014/09/gdrive-simple-google-drive-cli-client.html> and <https://github.com/prasmussen/gdrive> for the github the repository.

From bash script a file can be uploaded to Google Drive using:

‘sudo -u www-data drive upload -p 0B1WIoyfCgifmMUwwcXNqeDl6U1k -f /home/pi/DFRobotUploads/dfrobot\_pivid.mp4 > /dev/null 2>&1 &’.

Explanation of this command:

When ‘drive’ runs as a new user and tries to connect to Google Drive, Google will first ask for a verification code. It provides a link to the Google Drive login page to get a verification code. One has to login with a valid Google Drive account to get a verification code for this account. The verification code serves as a login code and will be stored locally in .json files on the Raspberry Pi in a ‘.gdrive’ subfolder of the home folder of the new user. Obviously these .json files must not be shared! From then on the new user has access to the Google Drive account.

To upload into the 'DFRobotUploads' folder, the -p option is used with the id of this folder. This id can be obtained using 'drive list -t DFRobotUploads'. When the 'DFRobotUploads' folder is changed, a new id has to be provided. The uploaded files have a distinctive name to enable finding and removing them again with the 'drive' utility.

## Communication through WhatsApp (outdated)

*Because WhatsApp does does not have a public API and does not support bots, using WhatsApp on a Raspberry by gives lots of trouble. Therefore WhatsApp is replaced by Telegram in September 2016. The description below is left for reference.*

The robot can also communicate through WhatsApp. This is done using Yowsup which is a Python library for connecting to WhatsApp. For installation the instructions on [http://www.instructables.com/id/Whatsapp-on-Raspberry-Pi/](http://www.instructables.com/id/WhatsApp-on-Raspberry-Pi/) are followed. After the installation the Yowsup setup must be run with:  
sudo python setup.py install

This is to enable Python to find all the dependencies.

A valid WhatsApp account is needed, registered on a phone number. With this phone number it is then not possible to use WhatsApp on another device, so it to best to use an otherwise unused phone number. After registering the robot is on WhatsApp and can send and receive messages.

WhatsApp registration:

1. Request a code with:  
   python yowsup-cli registration --requestcode sms --phone 316xxxxxxxx --cc 31 --mcc 204 --mnc 04  
   An SMS will be sent to the phone number with a WhatsApp code, for example 691-663. Therefore it is needed to put the associated SIM card in an existing phone which can receive SMS messages.
2. Request registration with:  
    python yowsup-cli registration --register 691-663 --phone 316xxxxxxxx --cc 31  
   Which returns something like:

INFO:yowsup.common.http.warequest:{"status":"ok","login":"316xxxxxxxx ","pw":"mBZ2lpfVJ39LK/7eRG/l2gkFsiI=","type":"existing","expiration":1471547176,"kind":"free","price":"\u20ac 0,89","cost":"0.89","currency":"EUR","price\_expiration":1448952682}

status: ok

kind: free

pw: mBZ2lpfVJ39LK/7eRG/l2gkFsiI=

price: € 0,89

price\_expiration: 1448952682

currency: EUR

cost: 0.89

expiration: 1471547176

login: 316xxxxxxxx

type: existing

1. Fill in the password in the Yowsup configuration file.
2. Send the first message using yowsup-cli demos --yowsup --config yowsup\_config as this might initialize for example the axolotl layer encryption.

It can happen that the WhatsApp account is corrupt, leading to messages like ‘no valid session’. Then:

* It could help to remove the axolotl database (used for encryption) at /home/pi/.yowsup/<phone number>/axolotl.db. If this does not help, continue with the below bullets. Recreate the database by sending a message using yowsup-cli demos --yowsup --config yowsup\_config.
* Connect to WhatsApp using using yowsup-cli demos --yowsup --config yowsup\_config and the /L command to connect.
* Use /account delete to delete the account.
* Re-register to WhatsApp starting with step 1 above.
* When connecting to WhatsApp from Yowsup is not possible anymore, try deleting the account from an official WhatsApp app, like installed on a MacBook using the BlueStacks Android simulator. Also this requires putting the associated SIM card in an existing phone. If the SMS message is not sent or received in 5 minutes, then simply wait. WhatsApp will ask in 5 minutes to call the phone by voice and speak out the WhatsApp code. Then register and delete the account from the WhatsApp app.

## Communication through Telegram

Telegram is a messaging system which does have a public Telegram API and a HTTP based bot API. Developers are encouraged to develop clients for both API’s. The Telegram bot can be created from any Telegram client by sending a ‘/newbot’ message to the Telegram user called ‘BotFather’. A bot account will be created by BotFather which returns a token. The bot can then can be accessed using the token through the bot API. To access the Telegram bot from the Raspberry ‘telepot’ is used. Telepot is a Python framework for the Telegram Bot API and is supported (not maintained) by the telegram.org.

Telepot can simply be installed with ‘sudo pip install telepot’.

## Apache webserver port configuration

To set the correct Apache webserver port edit ‘/etc/apache2/ports.conf’ and change port 80 to 44444:

NameVirtualHost \*:44444

Listen 44444

In addition in ‘/etc/apache2/sites-enabled/000-default’ change the first line from <VirtualHost \*:80> to <VirtualHost \*:44444>.

## Apache webserver password protection

See <http://www.debiantutorials.com/password-protecting-a-directory-with-apache-and-htaccess/>.

The DFRobot website is protected by letting the Apache server protect the ‘/var/www’ directory, where the index.html file is located. The file ‘/etc/apache2/sites-enabled/000-default’ is modified to contain:

<Directory /var/www/>

AllowOverride All

</Directory>

This enables ‘.htaccess’ file support in ‘/var/www’.  
A ‘.htaccess’ file is created and placed in /var/www (where the index.html file is located) to protect the complete DFRobot website:

AuthType Basic

AuthUserFile /etc/apache2/.htpasswd

AuthName "Enter password"

Require valid-user

It points to ‘/etc/apache2/.htpasswd’ which contains the password for user ‘reneb’. The command ‘htpasswd -c /etc/apache2/.htpasswd reneb’ can be used to generate a new password for user ‘reneb’.

## Enable .py scripts with CGI in Apache2

Open ‘/etc/apache2/sites-enabled/000-default’ (this is a link to the file ‘default’) and add  
’AddHandler cgi-script .py’ to the section

<Directory "/usr/lib/cgi-bin">  
...  
</Directory>

Then reload Apache’s configuration using ‘sudo service apache2 reload’.

When running Python scripts from Apache2 through CGI the user is ‘www-data’. So scripts and external program run must have the proper group permissions.  
When using the camera module the VideoCore device ‘/dev/vchiq’ is used. The default permissions are:  
crw-rw---T 1 root video 250, 0 Jan 1 1970 /dev/vchiq  
These permissions mean that www-data cannot read from ‘/dev/vchiq’ which will give the ‘failed to open vchiq instance’ error when trying to use the camera from CGI Python. It can be seen that the user group ‘video’ is assigned to ‘/dev/vchiq’.

To be able to run the camera from CGI Python: ‘sudo chmod 666 /dev/vchiq’ works, but the original permissions are reset on reboot.  
So a permanent solution is to make the www-data (www-data is the user under which the Apache2 web server runs) member of the video group. This can be done with: ‘sudo adduser www-data video’.  
To enable a script which runs as www-data to use sudo without password the line ‘www-data ALL=(ALL) NOPASSWD: ALL’ has to be added to the end of /etc/sudoers. This can be done using the ‘sudo visudo’ command. This is needed for example to kill a process of another user than www-data.

## Bash scripts versus Python scripts with CGI in Apache2

When using Python CGI the problem is encountered that for each http POST method call the Python interpreter on the Pi must be loaded and the Python script executed. This can take 1 to 3 seconds, depending if video is streaming or not. As this is not an acceptable delay I decided to switch from Python CGI to bash CGI which is much faster.

The bash scripts used can be called without ‘bash’ in front , but make sure it start with ‘#!/bin/bash’ (and not #!/bin/sh) to use the bash shell.

## Enabling I2C on the Raspberry Pi

Information taken from <http://www.legomindstormsrobots.com/arduino/connecting-arduino-raspberry-pi-i2c/>  
The Raspberry Pi board is connected to the Arduino board through I2C. The Raspberry Pi is the I2C master and has internal pullup resistors for the SDA and SCL line.

Enable the I2C hardware by adding at the end of /etc/modules:  
i2c-bcm2708

i2c-dev

Next install the i2c-tools utility:

‘sudo apt-get install python-smbus’.

‘sudo apt-get install i2c-tools’.

If /etc/modprobe.d/raspi-blacklist.conf exists, comment out the lines  
blacklist spi-bcm2708

blacklist i2c-bcm2708

From kernel version 3.18 on (‘uname –a’ shows kernel version): to use GPIO2 (pin 3) and GPIO3 (pin 5) as SDA and SCL respectively, add ‘dtparam=i2c=on,i2c\_baudrate=32000’ at the end of /boot/config.txt. The last part sets the i2c speed to 32 kbit/s. The default baudrate is 100 kbit/s which seems to be too fast for the Arduino; when using this baudrate an occasional ‘[Errno 5] Input/output error’ is observed when executing the Python ‘bus.read\_byte\_data()’ or ‘bus.write\_byte\_data()’ function.  
Add the pi user to the i2c group, to do this type ‘sudo adduser pi i2c’.

The I2C devicescan be scanned using ‘i2cdetect -y 1’.

To allow usage of the I2C device by www-data:  
‘sudo adduser www-data i2c’.

Finally, in ‘/lib/udev/rules.d/60-i2c-tools.rules’, change  
KERNEL=="i2c-[0-9]\*", GROUP="i2c", MODE="0660"

to  
KERNEL=="i2c-[0-9]\*", GROUP="i2c", MODE="0666"

to have the I2C device readable by the i2c group.  
Then reboot using ‘sudo reboot’.

## Enabling the hardware watchdog on the Raspberry Pi

To make the system more robust a hardware watchdog is used. The idea is to reboot the system as soon network connection is lost.

* First install the watchdog kernel module with:  
  ‘modprobe bcm2708\_wdog’
* To make the watchdog module loaded automatically at boot time, set in ‘/etc/default/watchdog’:  
  # Start watchdog at boot time? 0 or 1  
  run\_watchdog=1  
  # Load module before starting watchdog  
  watchdog\_module="bcm2708\_wdog"  
  # Specify additional watchdog options here (see manpage).
* Install a watchdog daemon and the chkconfig tool (to activate and deactivate services) with ‘sudo apt-get install watchdog chkconfig’.
* Enable the watchdog service with ‘sudo chkconfig watchdog on’.
* Start the watchdog with ‘sudo /etc/init.d/watchdog start’.
* Edit ‘/etc/watchdog.conf’ to set what should be checked by the watchdog daemon. For example to check if the router can be pinged:  
  ‘ping = 192.168.1.254’  
  To check if a file has been updated the ‘file’ and ‘change’ settings can be used. Unfortunately both options do not work, the Raspberry Pi is rebooting continuously. This is a known problem. It seems that when the watchdog daemon is not started correctly when using these options. It seems to do with:  
  *For those who want the gruesome details: wd\_keepalive is supposed to prevent the watchdog (hardware) from timing out during boot. After boot-up watchdog (software) is meant to kill wd\_keepalive and take over. Problems with the startup scripts mean that this isn't happening: wd\_keepalive continues to run and conflicts with watchdog (software), causing the watchdog (hardware) to time-out prematurely. In fact wd\_keepalive isn't needed, because the watchdog (hardware) isn't enabled until watchdog (software) loads. There, clear as mud.*Also at instructables found the remark: ‘If the Raspberry Pi takes longer to bootup than 14 seconds (or to whatever value you set Wto), the WatchDog can fire which puts the Raspberry Pi in an infinite bootup sequence’. The 14 seconds is a hardware limit so it cannot be increased.
* Manually starting the watchdog daemon with these settings after boottime does work, but is not practical.  
  Therefore we currently use the setting:  
  #file = /usr/local/bin/own\_watchdog.sh  
  #change = 40  
  watchdog-device = /dev/watchdog  
  realtime = yes  
  priority = 1  
  The ‘own\_watchdog.sh’ bash script (see below) runs continuously and checks for the network connection. If all is ok it updates its modification timestamp to let the watchdog know all is ok. If the timestamp is not updated for 40 seconds, the system will reboot.  
  As mentioned above the ‘change option does not work, the Raspberry Pi gets in a infinite reboot loop.   
  Therefore the ‘file’ and ‘change’ lines are commented out. What does work is that the watchdog is running and when for example the Wifi dongle is unplugged and plugged in again, the system reboots and thus recovers. In combination with the ‘own\_watchdog.sh script which reboots when ping fails, we have a robust failure recovery.
* The watchdog can be tested by adding watchdog\_options="-v -q" to /etc/default/watchdog. With these options the watchdog will only log but not actually reboot. The log can be checked in /var/log/daemon.log.
* Update 25072015: The Raspberry Pi 2 Model B seems to have the same problem as described above. Also at instructables found the remark: ‘If the Raspberry Pi takes longer to bootup than 14 seconds the WatchDog can fire which puts the Raspberry Pi in an infinite bootup sequence’.

## Creating a custom software watchdog bash script ‘own\_watchdog.sh’ on the Raspberry Pi to check the network connection

A custom watchdog in the form of a bash script is created. This script checks whether the router (192.168.1.254) or the Samsung Wifi hotspot (192.168.43.1, this is hardcoded in Android) can be pinged. If both cannot be pinged, it does not update its modification timestamp. This will be detected by the watchdog which will then reboot the system in about 15 seconds.  
  
#!/bin/bash

# Start with a touch of this script to feed the watchdog daemon a.s.a.p.

prompt=$(basename $0)

# Reset the log file to zero length if the size gets too large.

if [ $(stat -c %s /home/pi/log/dfrobot\_log.txt) -gt 1000000 ]

then

echo -e "\*\*\*\*\* $(date), $prompt: START LOG \*\*\*\*\*" > /home/pi/log/dfrobot\_log.txt

else

echo -e "\n\*\*\*\*\* $(date), $prompt: START LOG \*\*\*\*\*" >> /home/pi/log/dfrobot\_log.txt

fi

count=0

touch -m $0

while [ 1 ]

do

# Start with a sleep to give network time to come up.

echo going to sleep

sleep 10

# Check for router and Android Wifi hotspot

if [ "$(ping -c 1 -W 2 192.168.1.254 | grep '100% packet loss')" -a "$(ping -c 1 -W 2 192.168.43.1 | grep '100% packet loss')" ]

then

echo "\*\*\*\*\* $(date), $prompt: ping failed, going to restart network!" >> /home/pi/log/dfrobot\_log.txt

echo ping not ok, going to restart network

sudo ifconfig wlan0 down && sudo ifconfig wlan0 up

sudo /etc/init.d/networking restart

sudo dhclient wlan0

else

# Touch this script to feed the watchdog daemon.

touch -m $0

# Write to logfile every 5 minutes when ping is ok.

if [ $count -ge 30 ]

then

echo "\*\*\*\*\* $(date), $prompt: ping ok" >> /home/pi/log/dfrobot\_log.txt

count=0

fi

fi

count=$((count+1))

done  
  
To have this script called after reboot add to the end of /etc/rc.local:  
‘/usr/local/bin/own\_watchdog.sh &’.

This way we have created:

* A hardware watchdog enabled by ‘run\_watchdog=1’ in ‘/etc/default/watchdog’ which is fed by a watchdog daemon configured in ‘/etc/watchdog.conf’.
* A software watchdog (‘/usr/local/bin/own\_watchdog.sh’)

These watchdogs run independent of each other.

‘/etc/init.d/watchdog status‘ or ‘ps –ef’ can be used to check that the watchdog daemon is running.

## Manually start run\_dfrobot.py

When manually starting run\_dfrobot.py for testing, first kill the currently running run\_dfrobot.py script. When starting again it can happen that the error ‘socket.error: [Errno 98] Address already in use’ occurs. With the command ‘lsof -i :12345’ the processes using this socket (12345 in this example) is listed. Once these processes are killed run\_dfrobot.py can be started.

## Scheduling a task to run at regular times

To schedule a task at regular times the standard ‘cron’ tool can be used. Use ‘crontab –e’ to edit the cron table.

To reboot the system every evening at 23:00 add the entry:

0 23 \* \* \* sudo shutdown -r now

To run the ‘run\_dfrobot.py’ script every hour add the entry:

0 \* \* \* \* /usr/local/bin/run\_dfrobot.py --log="/home/pi/log/dfrobot\_runlog.txt"

To run the ‘run\_dfrobot.py’ script after a reboot:

@reboot /usr/local/bin/run\_dfrobot.py --log="/home/pi/log/dfrobot\_runlog.txt" &

Or add it at the end of /etc/rc.local:

/usr/local/bin/run\_dfrobot.py --log="/home/pi/log/dfrobot\_runlog.txt" &

When running from cron the PATH environment variable does not contain ‘/usr/localbin’ so use the full paths for these commands in the run\_dfrobot.py script.

Setting the timezone right can be done with:

‘sudo cp /usr/share/zoneinfo/Europe/Amsterdam /etc/localtime‘.

To check in bash whether there are active connections one can use:

‘netstat -an | grep -E \'44444.\*ESTABLISHED|44445.\*ESTABLISHED\' | wc -l’.

This way connections to port 44444 and 44445 are counted. This can be handy to prevent the robot from taking autonomic actions when a person is operating it through the webbrowser.

## Threading in Python

For reading the images from the MJPEG input stream a separate thread is created using the Python method thread.start\_new\_thread(). This thread reads the input stream at maximum speed while another thread can do the image processing. This solves the input buffering problem when reading from the MJPEG input stream. Communication between the threads is done using lock objects (not semaphores, which are a more advanced locking mechanism).

Also for the Telegram client and for the Socket client separate threads are generated. Important to note is that each thread must preempt itself at regular intervals otherwise other threads will not run at regularly. A time.sleep(0.001) is sufficient.

## OpenCV attempt 1: building and installing OpenCV from source on the Raspberry Pi

OpenCV (Open Source Computer Vision) is used by the robot to recognize markers in its environment, and use these to navigate. Installing OpenCV is done by following the guide on <http://www.pyimagesearch.com/2015/02/23/install-opencv-and-python-on-your-raspberry-pi-2-and-b/>. However, step 9 – Setup the build failed. It turned out that the default installed gcc 4.6 was corrupt and gave a ‘segmentation fault’ when trying to compile any C++ file. As a resolution gcc 4.7 was installed following <http://www.rpiblog.com/2014/07/installing-gcc-on-raspberry-pi.html>. After this step 9 - Compile OpenCV failed at 75%. The file ‘libpython2.7.so’ seemed to be corrupt. This was solved by issuing ‘sudo apt-get -y remove libpython2.7 python-dev python2.7-dev’ and then ‘sudo apt-get -y install libpython2.7 python-dev python2.7-dev’.  
Then openCV seemed to to be installed from Python but when issuing ‘cv2.imshow("Image", image)’ there is the error: ‘OpenCV Error: Unspecified error (The function is not implemented. Rebuild the library with Windows, GTK+ 2.x or Carbon support. If you are on Ubuntu or Debian, install libgtk2.0-dev and pkg-config, then re-run cmake or configure script) in cvShowImage, file /home/pi/opencv-2.4.10/modules/highgui/src/window.cpp, line 501’. It seems to be related to a missing libgtk. This is a toolkit for creating graphical user interfaces required for the OpenCV highgui, see step 3 of OpenCV installation guide mentioned above. However reinstalling libgtk2.0-dev did not help.

This means that in the end building and installing OpenCV on the Rasberry Pi did not work out.

## OpenCV attempt 2: installing a precompiled OpenCV on the Raspberry Pi

From <https://github.com/Nolaan/libopencv_24/releases> a precompiled version of OpenCV for the Raspberry can be downloaded. It can be installed with ‘dpkg -i libopencv\_2.4.11.deb’. After doing this an ‘import cv2’ sais ‘ImportError: No module named cv2’. This is fixed after installing the Pyhon bindings with: ‘sudo apt-get install libopencv-dev python-opencv’. However then an ‘import cv2’ gives a segmentation fault. This was solved by:

* Fixing a corrupt gcc by installing gcc 4.7 by following <http://www.rpiblog.com/2014/07/installing-gcc-on-raspberry-pi.html>
* Fixing the python2.7 installation by issuing ‘sudo apt-get -y remove libpython2.7 python-dev python2.7-dev’ and then ‘sudo apt-get -y install libpython2.7 python-dev python2.7-dev’.

After this the OpenCV works on the Raspberry Pi!

## OpenCV attempt 3 (and final): installing the OpenCV libraries and python-opencv

The simplest way to install OpenCV is like it is described in <http://petrkout.com/electronics/low-latency-0-4-s-video-streaming-from-raspberry-pi-mjpeg-streamer-opencv/> and on <https://www.piborg.org/diddyborg/install>: sudo apt-get install libopencv-dev python-opencv python-numpy. The standard openCV libraries are installed together with python-opencv (library of Python bindings). Advantage is straightforward package installation. Disadvantage is that not the newest version will be installed.

In addition the following is needed to make it work:

* Fixing a corrupt gcc by installing gcc 4.7 by following <http://www.rpiblog.com/2014/07/installing-gcc-on-raspberry-pi.html>
* Fixing the python2.7 installation by issuing ‘sudo apt-get -y remove libpython2.7 python-dev python2.7-dev’ and then ‘sudo apt-get -y install libpython2.7 python-dev python2.7-dev’.

After this the OpenCV works on the Raspberry Pi!

## OpenCV pattern matching

To let the robot find its way Python-OpenCV is used to recognize specific objects. As input OpenCV reads the http MJPEG stream as a sequence of jpg frames. These are analyzed and the result is drawn back into the image, for example as a rectangle around the recognized object.

The sequence of processed images is converted to a mpeg-4 video using MEncoder. This video can be uploaded to Google Drive.

The following alorithms have been investigated:

* Finding patterns with cv2.matchTemplate().  
  This works by finding a match of a template image within the input image. This works quite well but is CPU intensive and only one template is matched at a time which is not very practical for robot navigation.
* Finding contours with cv2.findContours(). This can be done by first thresholding the picture on colors with cv2.inRange() and then finding the contours. This works well, but the difficulty is in finding a good color range. This way for example it is possible to detect for blue shapes but the performance is very dependent on the lighting conditions.
* Finding blobs with cv2.SimpleBlobDetector(). This works on a grayscale input image. Blob filtering can be done by color, size and shape. This way for example circles can be searched. As the blob detection algorithm itself converts the grayscale image to a binary image using different threshold levels the performance is quite independent of the lighting conditions. Up till now this is the best performing algorithm which is useful for robot navigation. Performance on a Rasberry Pi 2B is about 2 frames per second on a 800 \* 600 image.

## OpenCV motion detection

To detect motion cv2.absdiff() is used to determine the difference between two grayscale images. The resulting difference image is then converted into a black-white image using cv2.threshold(). The function cv2.findcontours() is used to find the contours of all motion areas. Finally the outer bounding box of all motion areas is calculated. Motion is considered true motion when the outer bounding box is not too large and occurs multiple images in a row. Global changes like the sun breaking through will not be considered as motion. The result is robust motion detection.

## Personal assistant on the Raspberry Pi

Features of the personal assistant:

* The personal assistant is triggered by two claps
* Voice specific commands can be executed.  
  Example 1: “James, news local”. The assistant will read the local news.  
  Example 2: “James, radio Latin”. The assistant will start internet radio with Latin music.
* Voice action commands can be executed.  
  Example 1: “James, demo”. The robot will execute a driving demo.  
  Example 2: “James alarm at 11:00”. The assistant will sound an alarm at 11:00.
* All other voice commands (starting with “James”) will be sent to a Knowledge Engine and the assistant will respond by voice.  
  Example: “James, Philips Stock”. The assistant will read the Philips stock price.

The above is implemented using the following techniques:

* Two claps triggering by timed energy measurements. The challenge is to detect the claps also when music (for example from internet radio) is playing through the loudspeaker which is close to the microphone. Therefore the clap detection algorithm first filters the audio signal using a bandpass filter around 4500 Hz. The filter is chosen such that it will reduce the music energy more than it reduces the clap energy. The filter comes from the SciPy package.
* Speech To Text (STT) is done by making use of the Google Cloud Speech API. For this an API key is needed which can be obtained from <https://console.cloud.google.com/>. Under ‘API-beheer’ -> ‘Inloggegevens’ the usage of the API key can be limited to specific IP addresses. This is to prevent usage and (billing) by others.
* Other STT engines are also supported, like IBM and Wit.ai. Wit.ai is able to translate natural language into an intent.
* Text questions are sent to the WolframAlpha knowledge engine. This engine can answer questions which are returned as text. An AppId is required which can be obtained after subscribing.
* Text To Speech (TTS) is done using the VoiceRSS service. For this an API Key is needed which can be obtained on request.
* The Python feedparser package is used to read RSS feeds, like the news.
* Internet radio is played using the MPD/MPC music player.

# Arduino Uno configuration

# Measurements

The measurements below were done on a Raspberry Pi 2 Model B using a digital Multimeter Dynatec 5010C.

The current measurements were done in the 10A current mode, and the terminals in series with the battery wires.

|  |  |  |
| --- | --- | --- |
| Voltage measurements with 6xAA batteries, batteries appr. 80% charged | | |
| Measurement | **Value** | **Remark** |
| Voltage before regulator, no current | 7.85 V | Measured at battery terminal |
| Voltage before regulator, current 320 mA | 7.55 V (7.51V) | Measured at battery terminal (measured at regulator) |
| Voltage before regulator at full current; 4 motors at max. speed | 7.15 V | Measured at regulator |
| Voltage after regulator, current 320 mA | 4.97 – 4.99 V | Measured at regulator |
| Voltage after regulator at full current; 4 motors at max. speed | 4.96 – 4.98 V | Measured at regulator |

|  |  |  |
| --- | --- | --- |
| Current measurements with 6xAA batteries, batteries appr. 80% charged | | |
| Measurement | **Value** | **Remark** |
| Raspberry Pi only, no Wifi dongle, no camera | 400 mA |  |
| Raspberry Pi only + Wifi dongle, no camera | 500 mA |  |
| Raspberry Pi only + Wifi dongle + PU` Aimetis Dual Lens USB Camera | 700 - 800 mA | Current varies |
| + Arduino + motor shield | + 40 mA | Delta current measured |
| + 4 motors at speed 100 | + 400 mA | Delta current measured |
| + 4 motors at full speed 255 | + 780 mA | Delta current measured |
| + 4 motors at full speed 255 and all blocking | + 2180 mA | Delta current measured |
| + Hitec HS-422 servo at rest | +8 mA | Servo library pin attach or detach does not influence rest current , when pin is attached servo position is ‘fixed’ |
| + Hitec HS-422 servo and blocking | +500 mA |  |
| Total current with Raspberry Pi + Wifi dongle + camera + 4 motors at full speed 255 | Appr. 1500 mA | Action mode |
| Total max. current with Raspberry Pi + Wifi dongle + camera + 4 motors at full speed 255 and all blocking | Appr. 3500 mA | Max. action mode |
| Light on (no other devices connected) | 380 mA | Two flashlights in series, 9 leds per flashlight |

|  |  |  |
| --- | --- | --- |
| Video delay measurements | | |
| Measurement | **Value** | **Remark** |
| No motors and using camera settings: --encoding mjpeg --width 800 --height 600 --quality 10 --framerate 10 --exposure auto --hflip yes --vflip yes | Appr. 0.1 s | Connection to laptop with local Wifi |
| 4 motors at full speed and using camera settings: --encoding mjpeg --width 800 --height 600 --quality 10 --framerate 10 --exposure auto --hflip yes --vflip yes | Appr. 0.1 s | Connection to laptop with local Wifi |
| No motors and using camera settings: --encoding mjpeg --width 800 --height 600 --quality 10 --framerate 30 --exposure auto --hflip yes --vflip yes | Up to 3 seconds. This delay is mainly in the network and not on the Raspberry; when pulling out the Wifi dongle the Raspberry the video on the Galaxy is continuing for about 2 seconds! | Connection to Galaxy S4 phone on 3G network, framerate 30 (to get more delay) |

|  |  |  |
| --- | --- | --- |
| Video bitrate measurements over Wifi with PU` Aimetis Dual Lens USB Camera | | |
| Measurement | **Value** | **Remark** |
| Camera settings: --encoding mjpeg –f 20 -r 1280x480 –co 50 -sh 1 | 15 Mbit/s, dependant of content. | Low sharpness, 1 connection open, measured using the ‘wavemon’ tool. |
| Camera settings: --encoding mjpeg –f 20 -r 1280x480 –co 50 -sh 50 | 20 Mbit/s, dependant of content. | Average sharpness, 1 connection open, measured using the ‘wavemon’ tool. |
| Camera settings: --encoding mjpeg –f 20 -r 1280x480 –co 50 -sh 100 | 23 Mbit/s, dependant of content. | High sharpness, 1 connection open, measured using the ‘wavemon’ tool. |
| Camera settings: --encoding mjpeg –f 20 -r 2560x960 –co 50 -sh 1 | 30 Mbit/s, dependant of content. | Low sharpness, 1 connection open, measured using the ‘wavemon’ tool. |
| Camera settings: --encoding mjpeg –f 20 -r 2560x960 –co 50 -sh 100 | 30 Mbit/s, limited by connection. | High sharpness, 1 connection open, measured using the ‘wavemon’ tool. |

# Operate the DFRobot using only 3G or 4G

Would it not be nice to be able to operate the DFRobot using only 3/4G? This makes it possible to operate the DFRobot in a remote area where only 3/4G is available, so virtually all over the world. No Wifi required! We will use a Samsung Galaxy S4 phone with a KPN Mobile 3/4G subscription for this experiment and a MacBook in a home network behind a router.

**The first step:**  
Without Wifi it is still possible to operate the DFRobot with an additional phone close to the DFRobot, using the phone’s Wifi tethering capabilities to connect to the DFRobot. Opening the phone’s browser the DFRobot webpage can be seen at <tethering IP address>:44444, for example 192.168.43.182:44444. This way the DFRobot can be operated from the Samsung phone provided the phone is close to the DFRobot.  
**The problem:**  
So far so good, but how can the DFRobot be accessed from any other location through the standard internet? Because the Samsung phone is connected to 3/4G through a provider like KPN Mobile it has no own IP address; when checking the IP address with <http://www.whatsmyip.org/> it will show a KPN Mobile IP address which is not directly related to the phone. This means the DFRobot cannot be accessed from the internet as such.  
It may be that when IPv6 is rolled out phones will get a unique public IP address which can be reached directly, but this can take a couple of years or more.  
**The solution:**Though the Samsung phone connected to 3/4G cannot be reached from the internet, the phone itself cán reach the internet! So the phone could first make a connection to the MacBook. Then a ‘tunnel’ is created which is used to let the MacBook access the DFrobot webserver through a standard browser. This can be accomplished by creating a so-called ‘SSH reverse tunnel’. It is called ‘reverse’ because the DFRobot phone has to initiate it but the tunnel itself is used in the other direction: from the MacBook running a browser and sending requests to the webserver running on the DFRobot. What happens is that first the Samsung phone sets up a standard SSH connection to the MacBook. Then an extra service is started to forward all traffic on port X from the MacBook back to port Y on the DFRobot phone. This is the ‘reversed’ tunnel. This technique is commonly used, for example to bypass firewalls.  
**Steps to set this up:**

* The Raspberry Pi must be able to connect to the Wifi hotspot of the Samsung phone. For this the Wifi credentials of the hotspot connection must be added to ‘/etc/wpa\_supplicant/wpa\_supplicant.conf’.
* On the router, assign a static IP address like 192.168.1.55 to the MacBook. This is needed because we need to forward the SSH port to the MacBook.
* On the router open SSH port 22 to the MacBook.
* On the Samsung phone install ‘ConnectBot’ which is an open source SSH client.
* In ConnectBot create an SSH connection to the MacBook.
* In ConnectBot add two port forwards to this connection:
  + Forward 1, type remote: from port 44444 (MacBook) to 192.168.43.182:44444 (Samsung phone)
  + Forward 2, type remote: from port 44445 (MacBook) to 192.168.43.182:44445 (Samsung Phone)

Two forwards are needed because the DFRobot webserver uses port 44444 for the html page and port 44445 for the MJPEG stream.  
In this case 192.168.43.182 is the address issued by the Samsung Wifi hotspot.

* On the Samsung phone activate Wifi hotspot. The Samsung phone will have the IP address 192.168.43.1 (hardcoded in Android).
* Now put the DFRobot and the Samsung phone in a remote area with 3/4G only.
* On the MacBook, open localhost:44444 in the browser and voilà!

**Experience:**The setup described works quite nice using a Samsung Galaxy S4 with a KPN Mobile 3/4G subscription. The DFRobot which is outside in a 3/4G area can be controlled from a MacBook using a standard browser. Controlling the DFRobot is about as fast as with a Wifi setup. The video performance might be less: the 1 second latency of the MJPEG stream became around 3 seconds in a specific situation (inside) but will obviously depend on the quality of the 3/4G connection. Otherwise the 3/4G experience is the same as the Wifi experience!

# Circuit diagram

# ../../../Downloads/DFRobotCircuit-20170708.png



# SD card images

Below a description of the SD card images created for the DFRobot project. It can be that the actual images are not available anymore because they had no added value.

The descriptions below are kept as they contain valuable information!

**SDcardBackup20150715.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This image was created just before installing openCV.

It contains a corrupt gcc compiler (4.6) and pyhon2.7 seems to be corrupt. Installing gcc4.7 and reinstalling Python can fix this. See DFRobot.docx.

**SDcardBackup20150717.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150715 as a starting point.

This image was created just after building and installing openCV (2.4.10).

This installation is built on the Raspberry Pi but in the end is not working (libgtk - highgui problem). See DFRobot.docx.

**SDcardBackup20150718.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150715 as a starting point.

This image was created just after installing a precompiled openCV (2.4.11).

This installation contains a working installation of OpenCV. It is installed from a precompiled version for the Raspberry Pi. See DFRobot.docx.

**SDcardBackup20150719.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150715 as a starting point.

This image was created just after installing the OpenCV libraries (2.4.1) and python-opencv.

The UV4L MJPEG streamer framework is removed because it was not compatible to OpenCV (premature jpg frames). Instead mjpg-streamer is installed.

In addition gcc4.7 is installed and python2.7 is reinstalled. See DFRobot.docx.

**SDcardBackup20150721.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150719 as a starting point.

In this image the low quality MJPG stream is set to 320x240. This to accommodate OpenCV processing.

A script runDFRobot.py is added in /usr/local/bin which uses OpenCV template matching and saves the processed images as a mpeg-4 video: dfrobot\_pivid.avi.

MEncoder is installed to create this video from a sequence of jpg images.

The bash script runDFRobot now calls runFRobot.py and uploads dfrobot\_pivid.avi to Google Drive.

A script homeDFRobot.py is added in /usr/local/bin which uses OpenCV template matching. This script is called when the home on button is clicked.

A home stop button is added to index1.html which kills the homeDFRobot python process.

**SDcardBackup20150722.gz: 8 GB Raspberry B+ image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150721 as a starting point.

The bash script runDFRobot is replaced by the python script runDFRobot.py.

The python script homeDFRobot.py is updated to goHomeDFRobot.py.

In addition the .sh extension is added to executable bash scripts for clarity.

**SDcardBackup20150730.gz: 8 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150722 as a starting point.

This is the first image running on the Raspberry 2B board. No modifications of the image were needed to run on the 2B.

goHomeDFRobot.py and runDFRobot.py are replaced by one script: run\_dfrobot.py.

This script can run in the Full run or in the Home run mode.

It uses cv2.SimpleBlobDetector() to find the garage and connect to the charging station.

A script compass.py is added which controls the GY-271 module with HMC5883L 3-Axis Digital Compass.

**SDcardBackup20150817.gz: 8 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150730 as a starting point.

A separate video thread is implemented to solve the video buffering problem. One thread continuously reads in the MJPEG images while another thread processed the images.

Motion detection is implemented. This is now the default process. It continuously analyses the incoming MJPEG stream for motion and uploads the motion video files to Google Drive.

Motion detection stops when a user makes connection to the robot. It continues when the user disconnects.

The PiCam is controlled by OpenCV to vertically center the target.

In addition the compass is used in relative mode so the garage can be in any orientation.

**SDcardBackup20150819.gz: 8 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150817 as a starting point.

A webpage refresh is forced whenever a new MJPEG stream is started so the user does not have to refresh the page himself.

Motion detection is now extended with contours for more robust performance.

run\_dfrobot.py is refactored and contains general constants, motion detection constants, blob detection constants and upload constants.

**SDcardBackup20150820.gz: 8 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150819 as a starting point.

WhatsApp client Yowsup installed to send and receive messages to and from WhatsApp.

As soon as motion is detected a text message or image is sent to WhatsApp.

**SDcardBackup20150822.gz: 8 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150820 as a starting point.

whatsAppClient() is now a separate thread handling incoming and outgoing messages.

Commands can be given via WhatsApp like sending a picture, report battery level.

Replaced own logging by Python logging and solved locking up problems.

**SDcardBackup20150920.gz: 16 GB Raspberry 2B image Wheezy kernel 3.18.11+.**

This installation used SDcardBackup20150822 as a starting point.

whatsApp.py is replaced by communication.py. In communication.py a socketClient thread is added.

This thread receives commands via a tcp/ip socket from the dfrobot.sh bash script.

So the dfrobot.sh bash script is called by the html page and forwards commands to the run\_dfrobot.py script.

In addition user www-data is added to /etc/sudoers to enable the use of sudo in the dfrobot.sh bash script.

This is needed for example to kill a process of another user than www-data in the dfrobot.sh bash script.

**SDcardBackup20151101.gz: 16 GB Raspberry 2B image Wheezy kernel 3.18.11-v7+ #781.**

This installation used SDcardBackup20150920 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* i2c\_cmd is replaced by Python script i2c.py which means all I2C communication is now done in Python.
* The I2C speed is set to 32 kbit/sec to prevent ‘Errno 5: Input/output error’ when executing the Python ‘bus.read\_byte\_data()’ or ‘bus.write\_byte\_data()’ function to communicate with the Arduino.
* In addition exception handling is added to the Python I2C code. This shows the 32 kbit/sec setting indeed fixes the ‘Errno 5: Input/output error’.
* Because of authorization error WhatsApp is re-registered (resulting in a new WhatsApp password) and Yowsup setup is re-run with sudo python setup.py install.
* Moved credentials to secret.py which is not on GitHub.

**SDcardBackup20151202.gz: 16 GB Raspberry 2B image Wheezy kernel 3.18.11-v7+ #781.**

This installation used SDcardBackup20151101 as a starting point.

* Cleaned downloaded packages with sudo apt-get clean.
* Scripts personal\_assistant.py and own\_gpio.py added.
* Installation of python-alsaaudio and mplayer to record and playback audio.
* Added ‘disable\_audio\_dither=1’ to /boot/config.txt to prevent noisy audio output.
* Installation of MPD/MPC music player to play internet radio.
* Installation of feedparser to parse RSS feeds.

**SDcardBackup20160102.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20151202 as a starting point.

* Installation of the SciPy package.
* Improvement of the clap detection algorithm by applying a bandpass filter from the SciPy package.
* Next to the Google STT (Speech To Text) engine, added support for the IBM Watson STT engine and the Wit.ai STT engine.
* ffmpeg package removed, replaced by the libav-tools package which contains avconv.
* Removed the rpi-update package as using this can corrupt the installation.
* Recreated the image using a smaller 16GB microSD card. This was needed to enabling copying back and forth the image to other 16GB SD cards. This was a complex operation involving the following steps:
  + Take a slightly smaller SD card (SanDisk Ultra 16GB) and put an older valid 8 GB image (SDcardBackup20150719) on this card.
  + Use an external USB microSD card reader to enable to read the SD card in a VirtualBox Ubuntu VM (internal MacBook 2011 SDXC (SD extended capacity) card slot cannot be accessed in VMware Fusion or VirtualBox).
  + In Ubuntu, use 'rsync -avx oldFilesystem newFilesystem' to copy the files of the latest image to both the FAT32 and Linux partition. ’rsync’ does a file level copy instead of a complete partition.
  + Put the newly created SD card in the Raspberry Pi and do a ‘sudo apt-get update’ and ‘sudo apt-get upgrade’.
  + Expand the Linux partition with ‘sudo raspi-config’ and selecting the ‘Expand Filesystem’ option.

**SDcardBackup20160326.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160102 as a starting point.

* Installed a new version of Yowsup (jlguardi fork) because of ‘Not-authorized’ error on login.
* Added DFRobotProfilePicture.jpg in /home/pi/yowsup directory.

**SDcardBackup20160501.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160326 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Changed socket connection from TCP to UDP, as only small commands and real time data is transferred.
* Installed a ultrasonic sensor HC-SR04 at the front. In own\_gpio.py the function ‘getUsSensorDistance()’ is added to read the sensor output. In communication.py the socketServer command ‘get\_distance’ is added so the distance can be read with a client socket. This can be used when a socket connection is made from game engine Unity.

**SDcardBackup20160703.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160501 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Update to yowsup 2.5.0.
* Added daily reboot in cron: 0 23 \* \* \* sudo shutdown -r now

**SDcardBackup20160730.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160703 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Moved handling of ‘reboot’ command from run\_dfrobot.py to dfrobot.sh to make sure it is executed; other threads might be corrupt.
* Fixed ‘globBrightness’ bug in run\_dfrobot.py so lights are not always switched on after the ‘home-start’ command.
* Added 3 seconds delay in ‘startWhatsAppClient()’ to make sure WhatsApp connects after a reboot.
* Added ‘whatsapp’ command to restart WhatsApp if needed.

**SDcardBackup20160918.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160730 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Replaced WhatsApp by Telegram.
* Upload to Google Drive commented out and replaced by sending to Telegram.

**SDcardBackup20161113.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20160918 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Added turning on lights if needed when getting a ‘picture’ request from Telegram.
* Update from Google Speech API v2.0 to the new Google Cloud Speech API v1beta1 (since 1 September 2016). Added speechContext with word hints to improve speech recognition.

**SDcardBackup20161127.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20161113 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* In own\_gpio.py modified the access permissions such that GPIO can be accessed without root permissions.
* In personal\_assistant.py added waitForProximity() to activate the personalAssistant() when the ultrasound distance sensor detects an object nearby. This replaces the two-claps detection in waitForClaps() which was not always reliable.
* Splitted speechToIntent() and personalAssistant() into speechToText(), textToIntent() and handleIntent(). This enables all Telegram messages to be handled by the same textToIntent() and handleIntent() as the speech commands.
* Refactored dfrobot.sh such that all commands are handled equal.
* Added Spanish news station ‘http://208.92.53.70:443/SER\_MALLORCA\_SC’.
* Added streaming audio from microphone to DFRobot webpage using VLC.

**SDcardBackup20170107.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20161127 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Changed radio Spanish radio station to <http://livestreaming.esradio.fm/stream64.mp3>.
* Changed radio Christmas radio station to <http://live.icecast.kpnstreaming.nl/skyradiolive-SRGSTR08.mp3>.
* Added continuous drive command and patrol mode.

**SDcardBackup20170704.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20170107 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Installed PU` Aimetis Dual Lens USB Camera.
* Added FPV (First Person View) mode.
* Updated mjpeg\_streamer from <https://github.com/jacksonliam/mjpg-streamer> to fix broken pipe issues when switching streams.
* Because of performance the resolution of the camera is set to 1280x480 and not to the maximum 2560x960. Framerate is set to 20 (lower is not possible), contrast to 50 and sharpness to 100 (range of contrast and sharpness is 0..100).
* Replaced Arduino move command by generic drive and turn command to support FPV mode.
* Replaced CGI by websocket communication.
* Improved command handling in run\_dfrobot.py. Multiple parameters separated by dots can be handled now.
* Improved parameters of the HomeRun mode.
* Changed radio Spanish radio station to <http://138.201.248.93/salsa>.

**SDcardBackup20170717.gz: 16 GB Raspberry 2B image Wheezy kernel 4.1.13-v7+ #826.**

This installation used SDcardBackup20170704 as a starting point.

* Run of sudo apt-get update and sudo apt-get upgrade to upgrade all installed Wheezy packages.
* Cleaned downloaded packages with sudo apt-get clean.
* Reverted back to use of Raspberry Pi camera as the PU` Aimetis Dual Lens USB Camera is broken.
* Added switching to external power when it is available. This is done using a relay. Switching from batteries to external power is when the robot is in the garage and only when the external power is stable. Switching from external power to batteries is done just before the robot starts driving out of the garage. This because during the power switch the robot is powered only by a capacitor so the robot cannot drive during the switch.
* When using the compass the light relay is switched off as its magnetic field can influence the compass by 10 degrees!
* Status of robot on webpage now indicates whether power is coming from external or from batteries.