Final Year Project

Pi0to
Chromic

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A report submitted to the University of Plymouth in partial fulfilment for the degree of BEng(Hons) Electrical and Electronic Engineering.

Glossary

Abbreviation	Meaning
SPI	Serial peripheral interface
LDR	Light dependant resistor
LCD	Liquid crystal display
FPGA	Field programmable gate array
VHDL	Very high speed integrated circuit hardware description language
IO	Input output
GPIO	General purpose input output
FoV	Field of view
TRL	Technology readiness level

Stage Criteria

This is the criteria that the project aims to meet, to feel as though the project had succeeded.

Stage	Name	Description
1	Smart shades	Make a set of smart sunglasses

Stage	Name	Description
2	Auto smart shades	Add LDR to control the opacity
3	Auto smart point shades	Add camera to make darks points over bright points
4	Controllable smart shades	Add options to swap between modes
5	Driving/safety improvements	Auto react to headlights etc.

Inspiration

The project was inspired by Linus tech tips video[1] about the IBuyPower Snowblind case[2]. It was then that the idea for reactive sunglasses using LCD was formed. While researching to see if this had already been done, ctrl-one glasses were discovered and have similarly been created[3].

The ctrl-one product starts down the same path as this project would like to take but are binary whereas this project aims for different levels of tinting and active shading. To achieve this it will be required to use an LCD panel with pixels instead of a single panel. Also, the ctrl-one products main unique selling points is the sub 0.1 second light to dark time[4]; which will ideally be surpassed. The other advantage this product will have over ctrl-one will be cost since, ctrl-one costs $299, while this product aims to be priced under £100[5] (set by the budget limit).

Plan

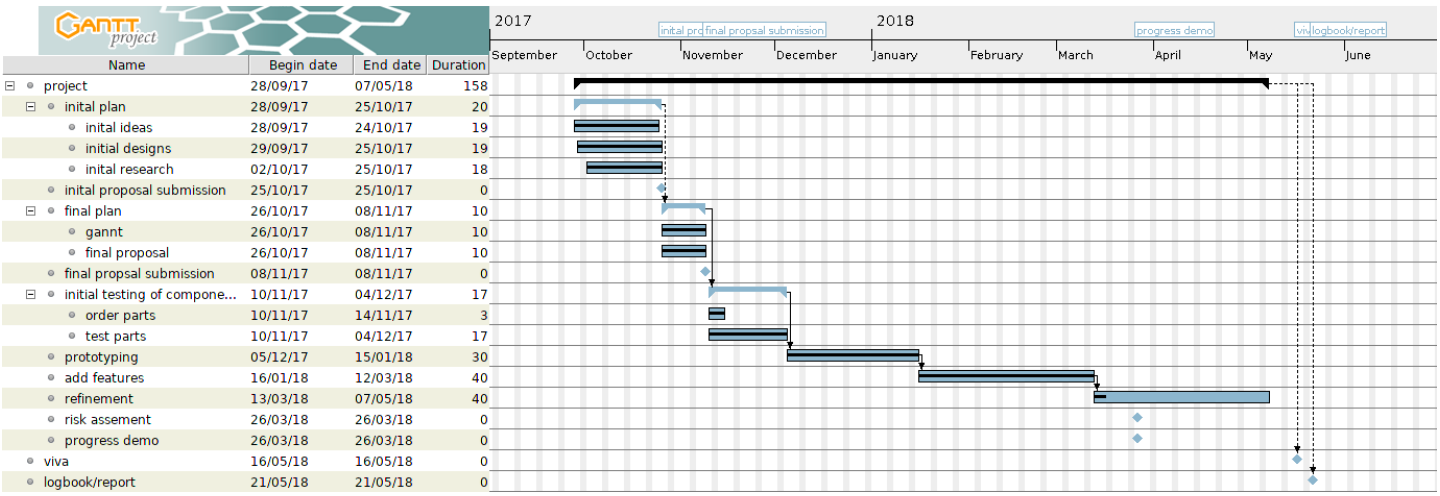
The products above, along with Paul Davey's lectures last year inspired the idea.

The plan is to use two LCD's with the backlight removed, to create dimmable panels in front of the users eyes. Then eventually a camera will added to create multiple point controls which will block bright spots such as projectors and sunlight thus, dimming them to reduce squinting.

Potential issues

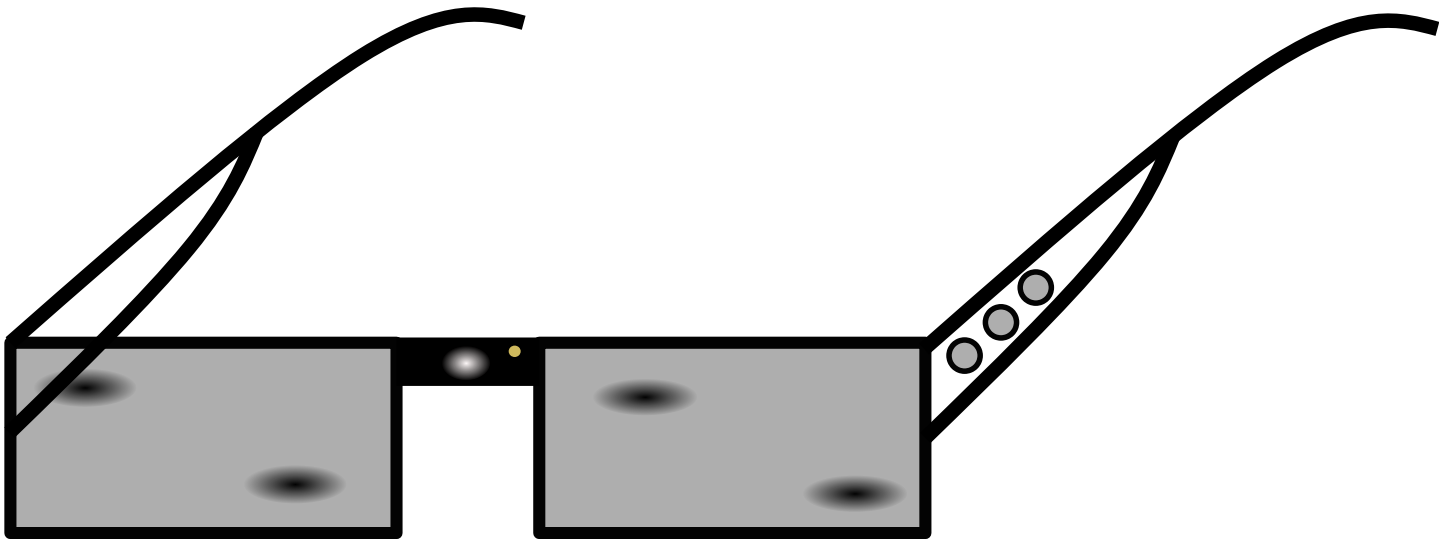
- IO speed, depending on the solutions used in the project could end up running into IO speed bottle necks affecting frame rate.
- Frame rate for the active points would need to be fairly high to stop nauseating effects.
- Camera distortion, a camera with little to no distortion would ideally be to used since this would make image processing easier.
- Field of view, having a similar FoV would be useful since a camera with smaller FoV would end up wasting the edge of the LCD.
- Aspect ratio, mismatch of aspect ratios without the use of accelerometers for predictive tracking could cause issues.

Timeline



Name	Begin date	End date	Duration
project	28/09/17	07/05/18	158
inital plan	28/09/17	25/10/17	20
inital ideas	28/09/17	24/10/17	19
initial designs	29/09/17	25/10/17	19
inital research	02/10/17	25/10/17	18
inital proposal submission	25/10/17	25/10/17	0
final plan	26/10/17	08/11/17	10
gannt	26/10/17	08/11/17	10
final proposal	26/10/17	08/11/17	10
final propsal submission	08/11/17	08/11/17	0
initial testing of compone...	10/11/17	04/12/17	17
order parts	10/11/17	14/11/17	3
test parts	10/11/17	04/12/17	17
prototyping	05/12/17	15/01/18	30
add features	16/01/18	12/03/18	40
refinement	13/03/18	07/05/18	40
risk assement	26/03/18	26/03/18	0
progress demo	26/03/18	26/03/18	0
viva	16/05/18	16/05/18	0
logbook/report	21/05/18	21/05/18	0

Final Mock-up



So, once the backlight was removed from the LCD's they can mount them into the frame. Then they can begin to be controlled by adjusting the contrast/pixel density to make them dim using a button. After which an LDR can be added to automate the brightness selection, the manual adjust however will be left in, at which point the button can still be used to switch between the different sensitivity levels.

Next a camera will be added to the system so that the system can detect bright points, hence make a matching point darker on the lens. At which point the buttons can be used so that you can switch between different modes. The final additional feature that will added is some intelligence on the camera side to ignore certain circumstances such as car tail/headlights.

Report

Compute

VHDL/FPGA(de0nano) vs. arm(STM32 vs. RPI)

For the compute unit the main options available are arm or FPGA. Theoretically the FPGA will have higher parallel thought put for the camera to LCD interface. Although arm will have image processing libraries which will expedite the prototyping process. The other main advantage with arm is the reduced cost.

Component	Quantity	Price(£)	Component type	Chosen
pi zero w	1	9.60	compute	yes
pi 3	1	35	compute	no
STM32	1	18.11	compute	no
de0nano	1	67.16 to 84.46	compute	no

I'm leaning towards the arm side since the camera will likely be 30-60 fps. I believe that an arm chip will be quick enough. Also it will have better support for interfacing the camera and LCD; the STM boards have analogue IO for the LDR and contrast for the LCD

After talking to supervisors and lab technicians they both recommended the raspberry pi as the platform. This recommendation is because of the price point of the zero w and the zero cam being so low as well as, the large product support for the increased range of screens possible. The only issue with this will be the fact the pi doesn't have analogue IO so the dimming of the LCD will be harder but this should be easily worked around.

Camera

Component	Quantity	Price(£)	Component type	Chosen
pi zero camera	1	15	camera	yes
pi camera	1	24	camera	no
ov7670	1	5 to 10	camera	no
ov7720	1	.50 from ps eye	camera	no

The options for the camera were good but the pi zero camera was picked, since it had the best compromise between cost and libraries[6].

LCD

LCD's will be used to reduce the amount of light reaching the users eyes. The way an LCD works is like a stain glasses window with a frosted glasses window and bight light behind. But with an LCD you can change the colour and brightness of the stain. This is the effect that will be used do dynamically adjust the amount of light reaching the users eyes.

Component	Quantity	Price(£)	Component type	Chosen
MCT0144C6W128128PML	2	7.57	lens	no
DD-12864YO-3A	2	16.12	lens	no
AF 1.8" TFT ST7735R driver	2	10	lens	yes

The Ada Fruit 1.8" TFT ST7735R is going to be the best option since its the best size for the lenses. Also there are drivers[7] available for the raspberry pi.

Theory

FIGURE 5: PATH OF LIGHT FOR OFF PIXEL (POSITIVE IMAGE)

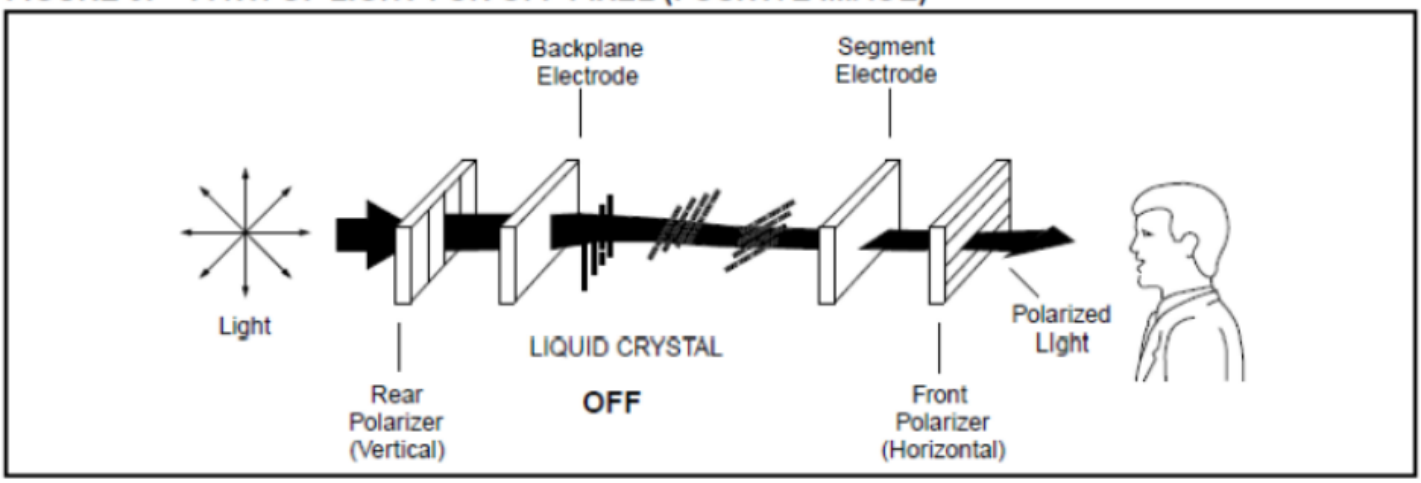
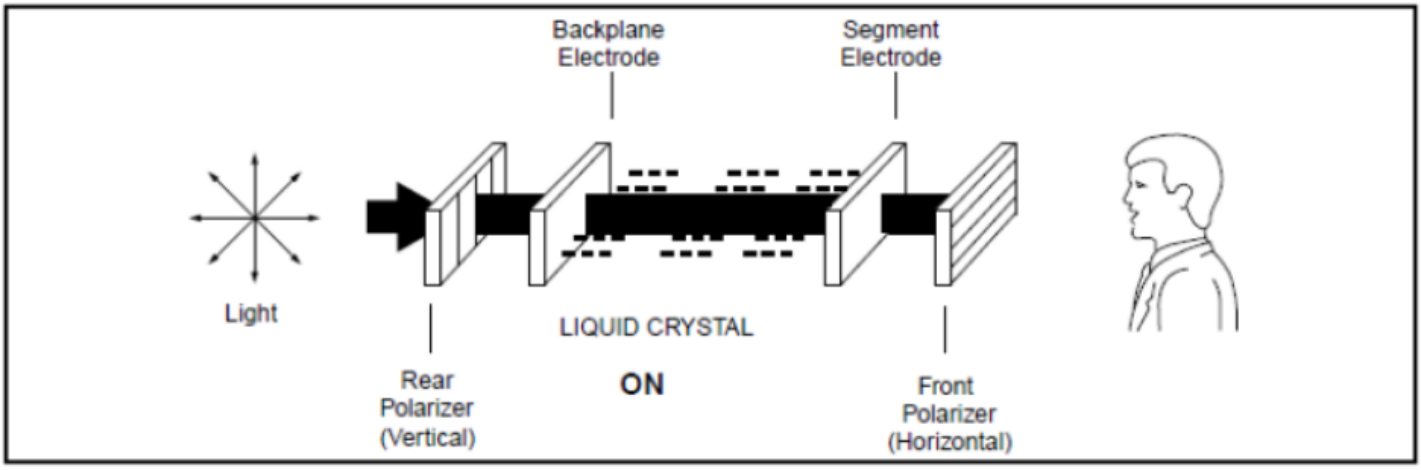


FIGURE 6: PATH OF LIGHT FOR ON PIXEL



In this diagram from Paul Davey's lecture[8] on LCD's last year, you can see the inner workings of an individual pixel.

This works like so;

1. Light enters the panel through the rear polariser. The light becomes vertically polarized.
2. The polarized light then passes through the transparent backplane electrode.
3. As the polarized light passes through the Liquid crystal fluid it gets twisted into the horizontal plane.
4. The polarized light passes through the transparent pixel electrode.
5. Because the light is polarized in the horizontal plane, it passes through the front horizontal polariser.

This is the effect that will be used reduce the amount of light reaching the users eyes.

Wiring

Function	Colour	Pi pins chip side	Pi pin	Colour	Function
vcc	Orange	17	18	Grey	rs
sda	Yellow	19	20	Black/P	gnd
N/A	nc	21	22	Blue	reset
scl	Green	23	24	White	cs

Testing

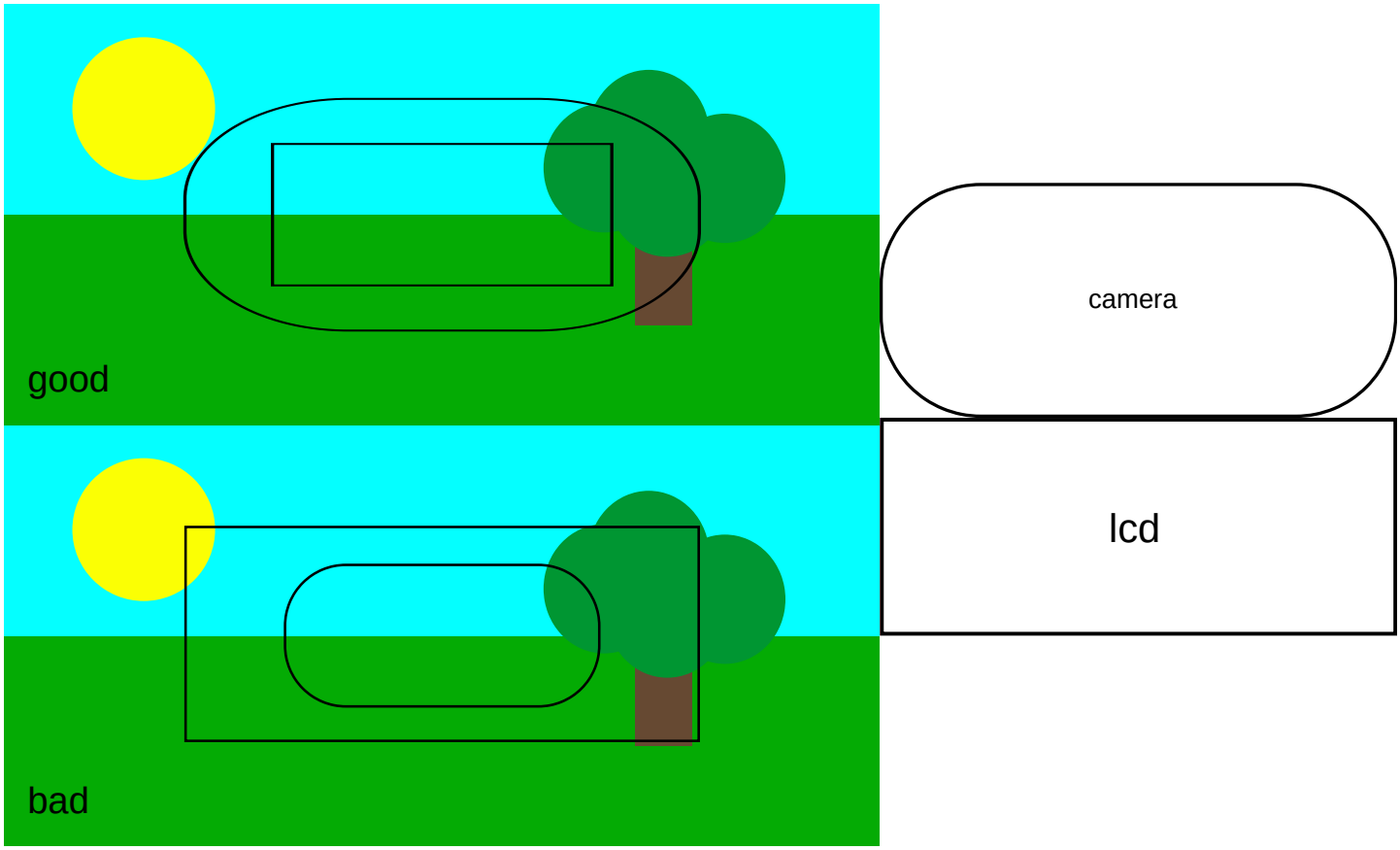
I connected the LCD and displayed some random size and location spots of different opacity on the screen.

random point video

After this, the entire screen was set to one tint, then changed to a different tint. This meant you could see the update "wipe" across the screen.

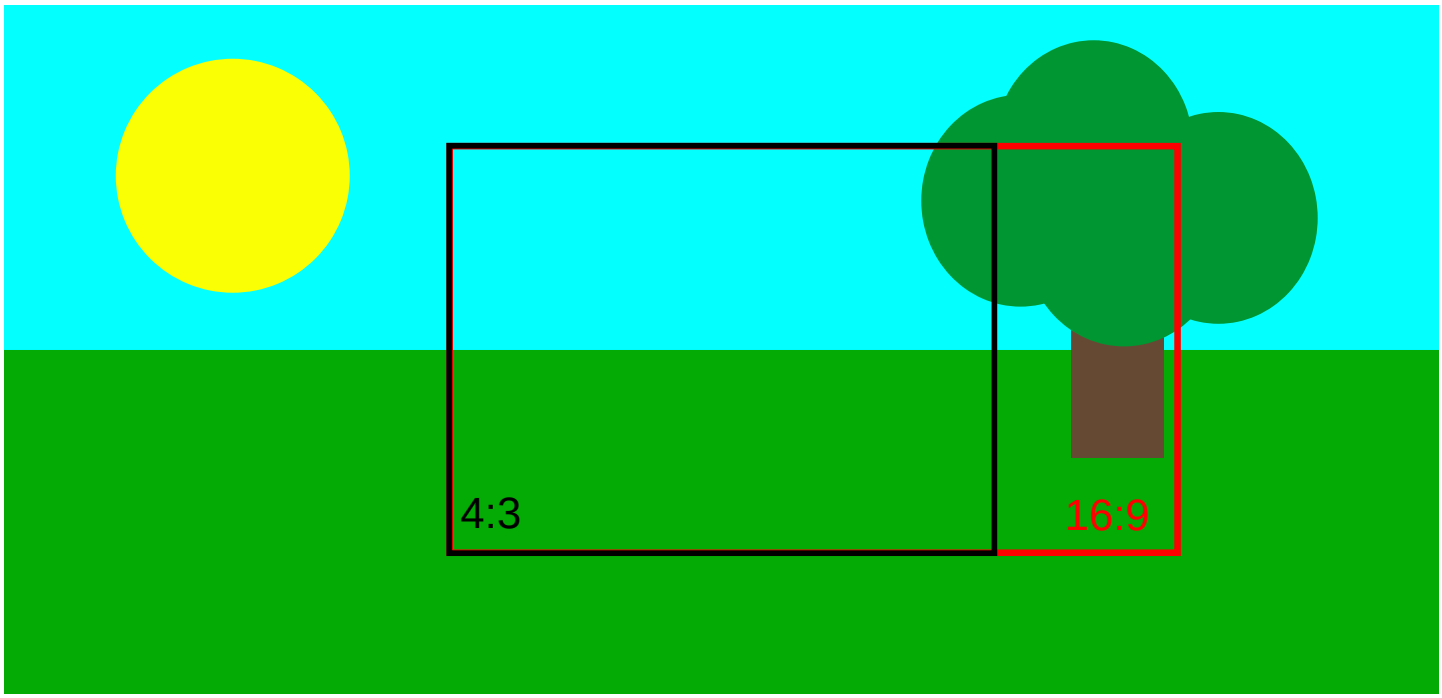
This will cause issues since the SPI is already at the max speed.

FoV

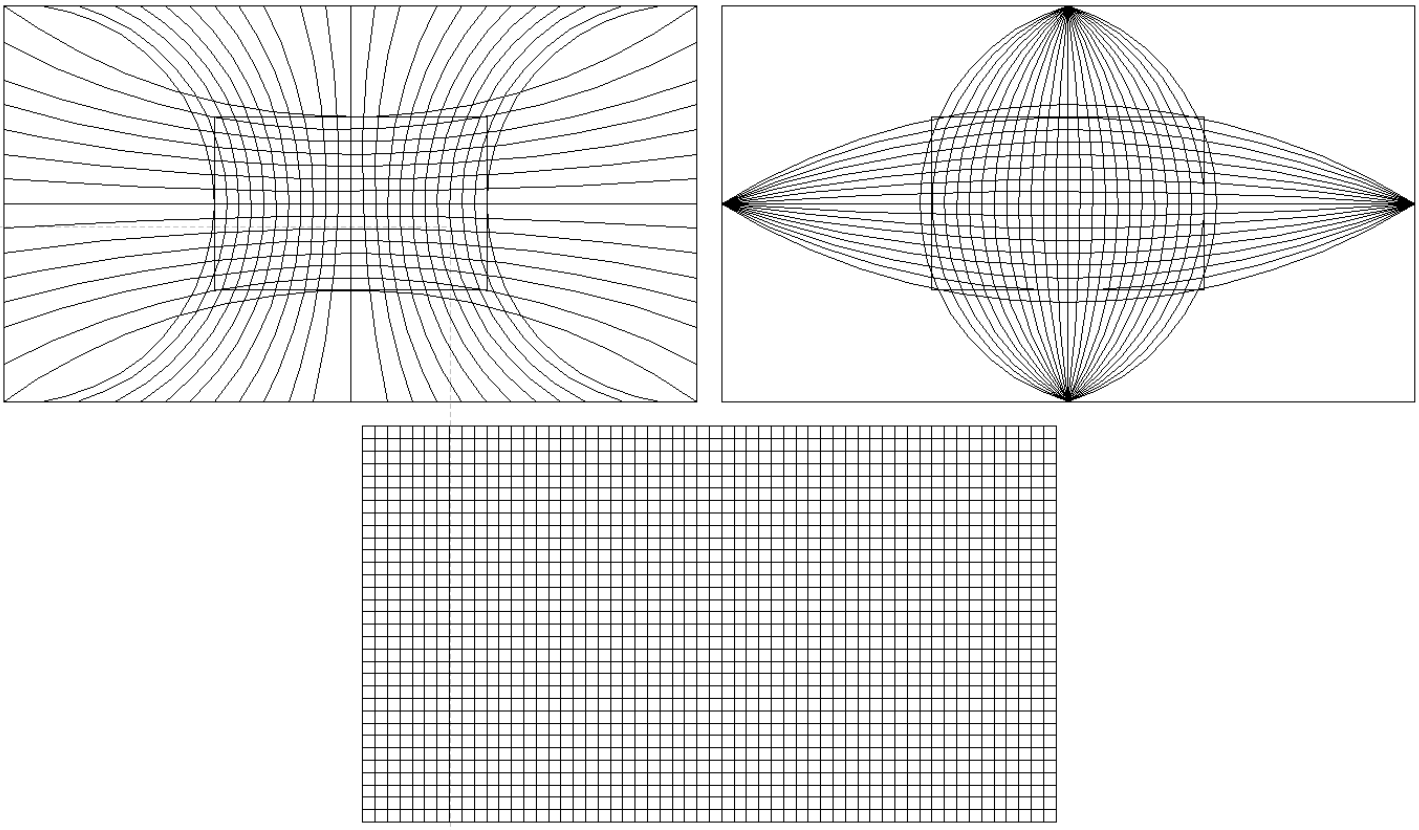


Field of view(FoV) is the area that you can can see. It is normally measured in degrees. For simple mapping it is required that the FoV of the camera and LCD to be the same. Other issues include;

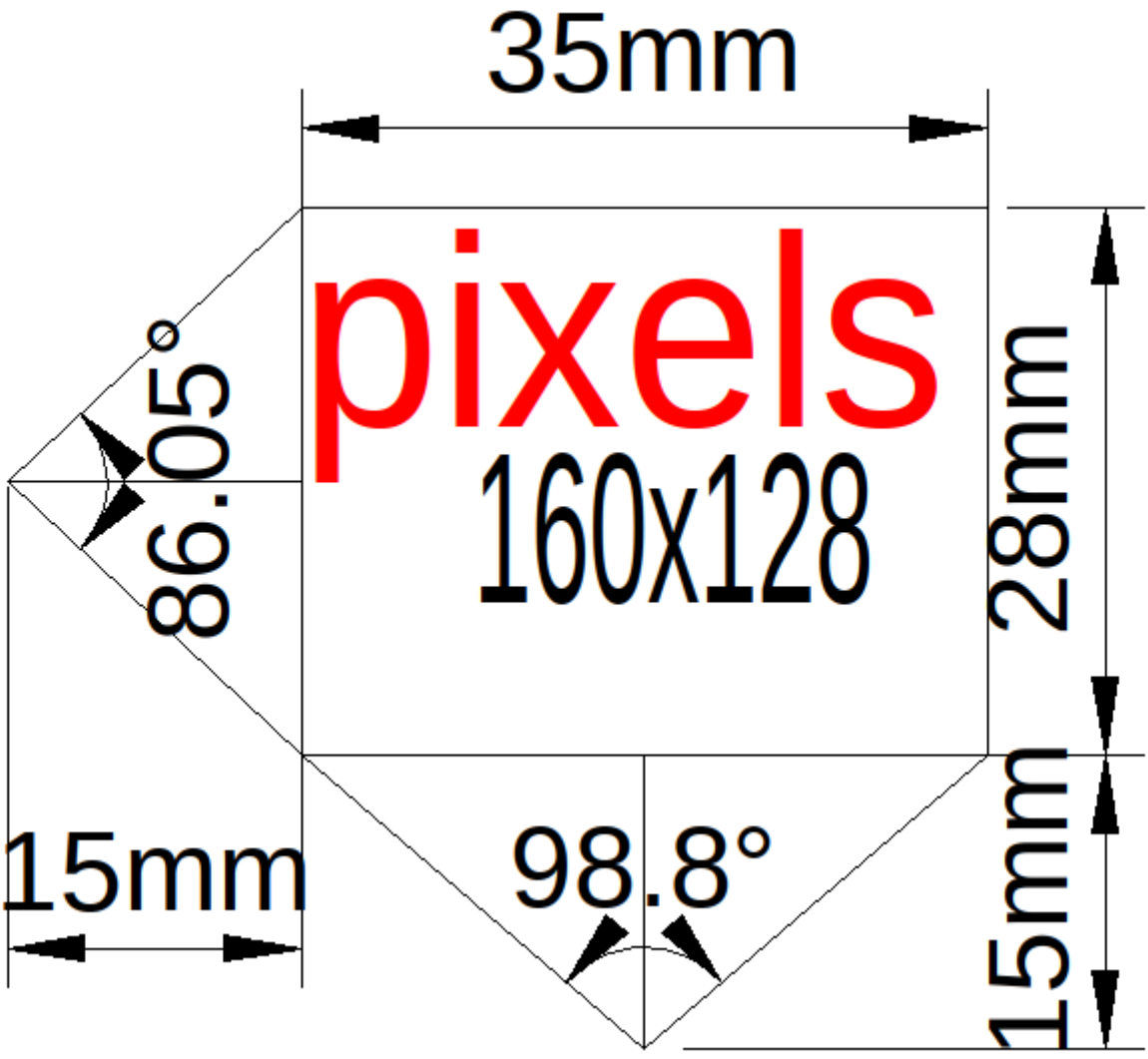
Aspect ratio



Distortion



LCD



160x128 pixels

98.8 degrees horizontal, 86.05 degrees vertical field of view

$$\frac{128}{86.05} = 1.48 \text{ vertical pixels per degree}$$

$$\frac{160}{98.8} = 1.62 \text{ horizontal pixels per degree}$$

Camera

2592x1944 pixels

53.50 degrees horizontal, 41.41 degrees vertical field of view

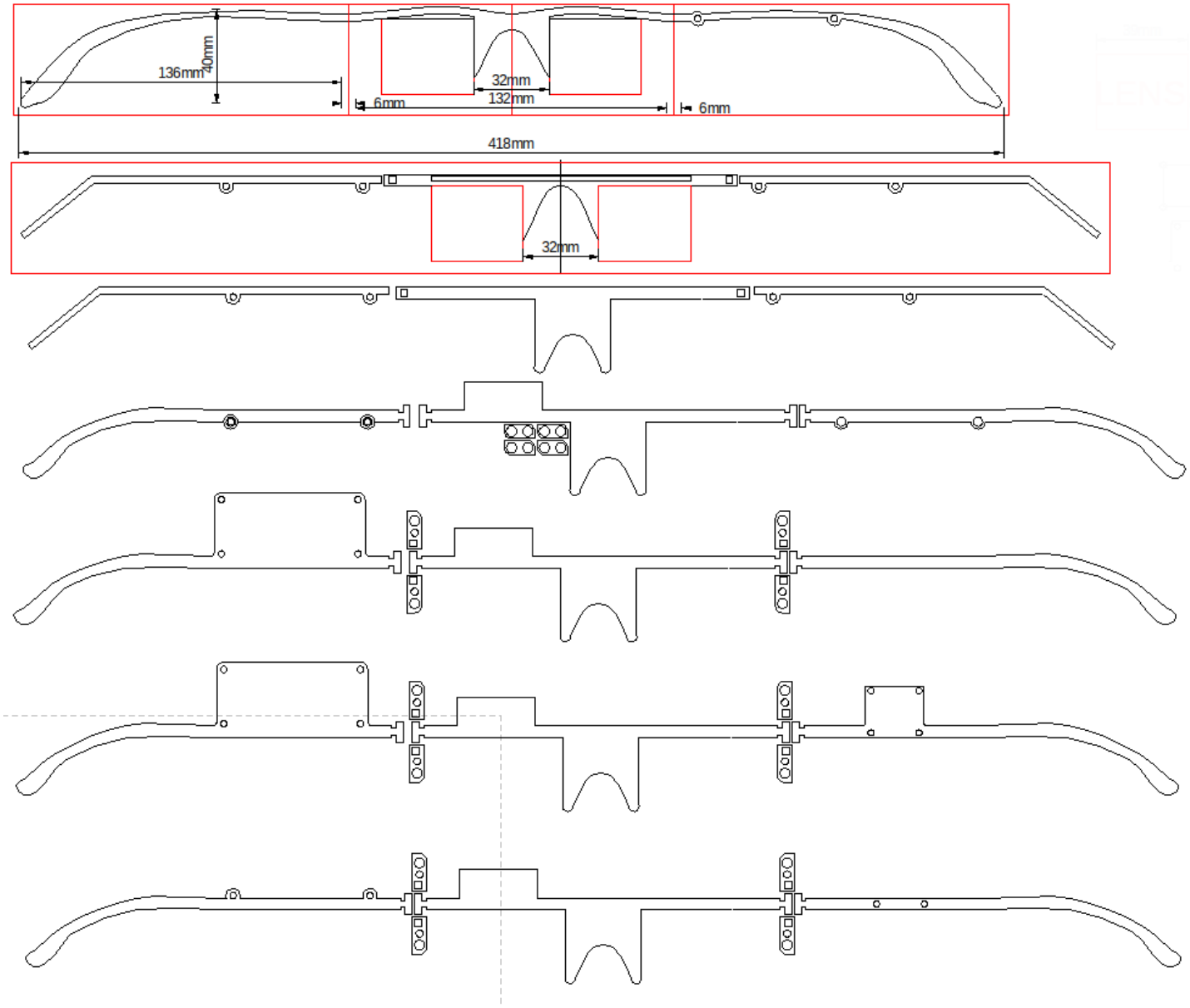
$$\frac{1944}{41.41} = 46.95 \text{ vertical pixels per degree}$$

$$\frac{160}{98.8} = 48.45 \text{ vertical pixels per degree}$$

So, this will cause issues since the dot placed on the LCD will end up in the wrong place without scaling.

Frame

The frame was cut by a laser cutter since this would be more cost and time effective. Also glasses frames tend to be fairly 2-dimensional. In the following image you can see the design iterations.



The initial idea was to heat the acrylic and bend at the red line, meaning that you wouldn't be able to fold them.

The next idea was another fixed design, but with a simpler shape. It was decided to go with this idea rather than the former so this was the first iteration that actually got cut. It was found that the lens was going to be too close to the eye and the ribbon cable from the lens was going to dig in to the brow of users nose. This was solved in the third iteration by making the increasing distance between the top of the frame and the top of the nose support. This forced the user to wear the glasses further down their nose.

After this, a hinging mechanism was designed and the curves re-added to make the glasses more comfortable. A mounting bracket for the camera was also added. This was the frame that cut and used for most of the prototyping phase of the project.

For the next two designs I was contemplating adding a backing plate to the pi mount and also adding a mount for the capacitive touch sensor. This design was never cut since the pi 0 needs clearance for the solder of the pin headers. Also the backing might have added too much weight. The design of the

hinge was furthered by squaring off one ends to make it more ridged and adding a hole to hold it together.

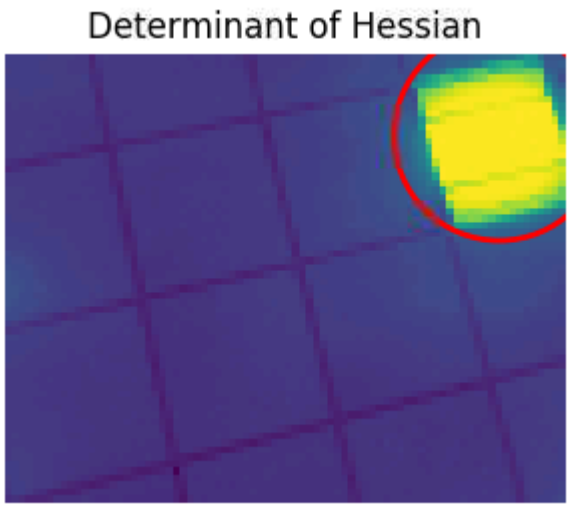
Blob Detection

The initial idea for blob detection was to import the grey scale image as a matrix of values. Then to iterate over it, looking for a difference in values or checking against a threshold value. However, it was difficult to get the image in as a matrix and even using an example matrix because the code wasn't running very quickly or reliably.

Installation of opencv for image processing was attempted but the install failed. After speaking to a supervisor he confirmed that opencv was too overpowered for my project.

More research was then done around low power blob detection in python. Skimage[9] (a library for python) was then found which has a function for Determinant of Hessian(DoH) blob detection. This was lightweight, meaning it would be quick enough for image processing. The only remaining issue was getting the image from the camera into the right format. Skimage has a built in numpy array converter which was fortunate since the DoH blob detection needs a numpy array to function.

With this working an image from the camera passed to the program, which saved the image with a circle around the blob to test the accuracy of the system.



I then connected the LCD and got blob detection working with that.

Telegram

Then shades.py (the file that controls the LCD and camera) and telegrambot.py (the script that enables remote control via a chat client bot) were converted to work together. This involved more work than was initially anticipated, since passing variables around wasn't as easy as hoped.

It was decided that telegram would be used to add remote control, so that you could adjust the colour of the tint remote control.

Commands

Command	Parameters	Description
help	N/A	Show the help menu.
pickcolour	Pick from list of tints	Preset tints/colours.
pickmode	Pick from list of modes	Change current mode.
tint	Percentage	Sets the tint of the lenses.

Command	Parameters	Description
image	N/A	Shows you the current image.
up	N/A	See if the bot is up.
temp	N/A	See the CPU temperature.
start	N/A	Starts shades.
stop	N/A	Stop shades.
exit	Admin only	Exit shades.
reboot	Admin only	Reboot shades.
halt	Admin only	Shutdown shades.
uprecords	N/A	See up time.
debug	N/A	Toggles debug.
buttons	Admin only	Toggles buttons.
colourset	fore/back@0/255,0/255,0/255	Sets the colour of the lenses.
allowallids	Admin only	Toggles if admin ID is needed.

Capacitive Touch Sensor

After the entire system was working a 5 button capacitive touch sensor was bought. The sensor was then added into the code, so that it would be able to control the glasses without the need for the glasses to be connected to the internet.

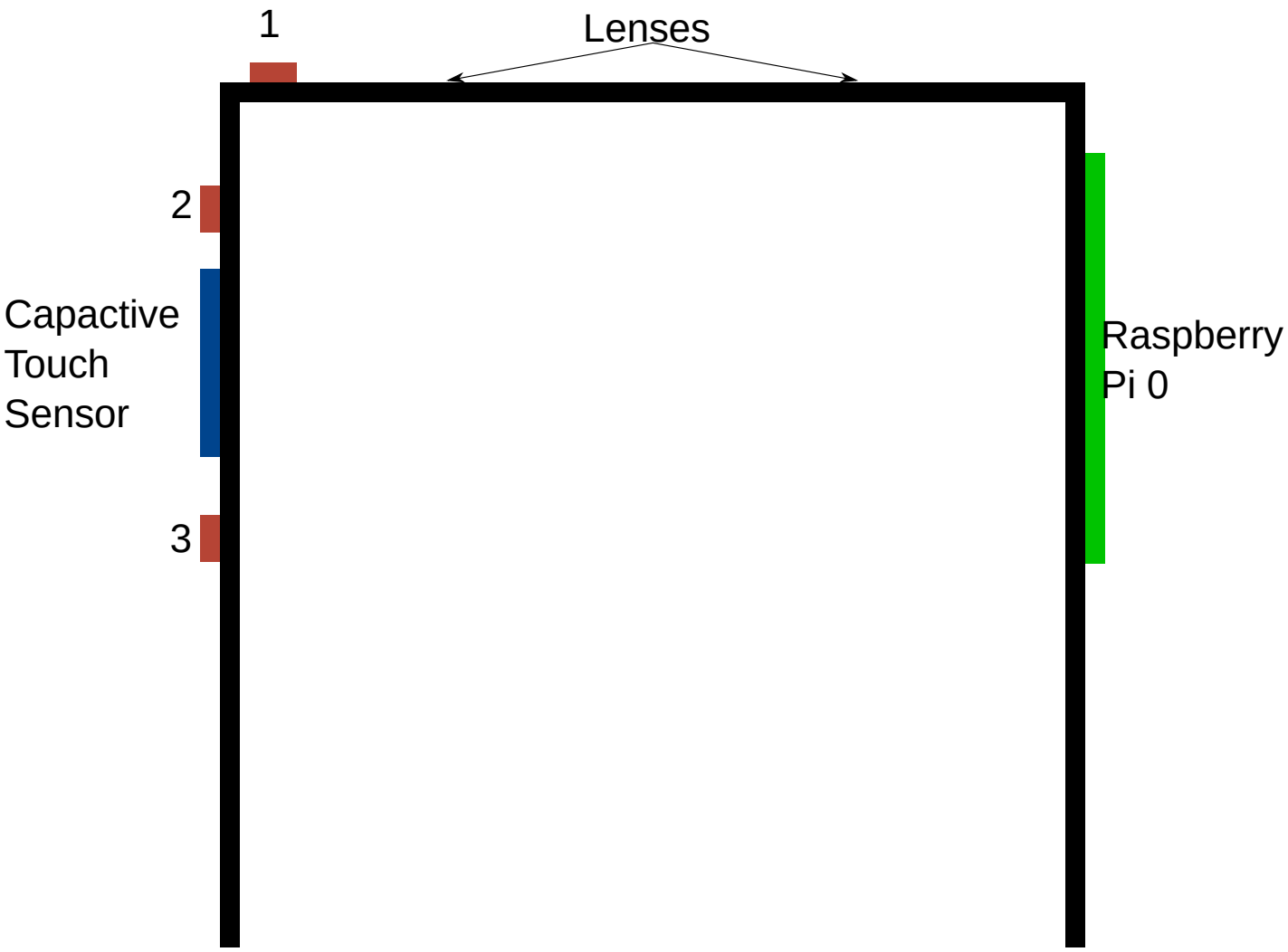
Wiring

Function	Colour	Pi pins chip side	Pi pin	Colour	Function
3.3v	nc	1	2	nc	5v
Button 1	Orange	3	4	Red	5v
Button 2	Yellow	5	6	Black	gnd
Button 3	Green	7	8	Blues	Button 4
gnd	nc	9	10	Purple	Button 5

Buttons

Button	Colour	Pressed	Held
1	Orange	Scroll tints	Reset tint to clear
2	Yellow	Scroll modes	Reset to manual
3	Green	Debug	Turn off
4	Blue	Stop	Start
5	Purple	N/A	Exit

For the final design only three buttons were used since the frame was beginning to get a bit cluttered with wires and boards.



It was also decided that it would be best to keep all the buttons on one side of the frame, since the capacitive touch sensitivity was a bit to high and you couldn't change it on this board. This meant you're less likely to have accidental readings from touching the wire if the wires are kept short and tucked out of the way.

Later Alex Baron suggested wrapping the sensor wire in thin pieces of wire to shield the wire by grounding the insulation. This worked really well.

Capacitive Touch Control

Mode change
Tint change
Debug toggle

Budget

Name	Price	Quantity	Total
pi0w	9.60	1	9.60
lcd	10	2	20
pi0 camera	15	1	15
pi0 pibow	4.19	1	4.19
pi0 metal case	3.99	1	3.99
hdmi to dvi-d	2.87	1	2.87
usb ampmeter	7.26	1	7.26
capacitve sensor	7.48	1	7.48
veroboard	3.60	1/4	.90
64GB Class 10 MicroSDXC UHS-1 Memory Card & SD Adaptor	23.95	1	23.95
total			94.25

Conclusion

Criteria Met

- [x] Make a set of smart sunglasses.
- [x] Add automatic of control the opacity.
- [x] Add camera to make dark points over bright points.
- [x] Add options to swap between modes.
- [ ] Auto react to headlight/safety improvements.

All of the stage criteria were met except reaction to headlights. It was decided that this wasn't a good idea, since this could interfere with the drivers sight, so this mode will be left out. Other safety

features added were resetting when you held any mode button. Except for a catastrophic error, the system is fail safe not deadly meaning it clears the LCD before exiting.

Finally an install script was made for the dependencies so that they would all be installed an configured correctly.

Existing market

Component	Price
pi 0 W	9.60
cap sensor	0.74
LCD	20
camera	15
total	45.34

This is considerably less than the existing market, so even with adding the fame and battery it will be cheaper.

Although the current refresh rate is lower at the moment, With a change of panel and main compute chip the system will be able to run considerably quicker.

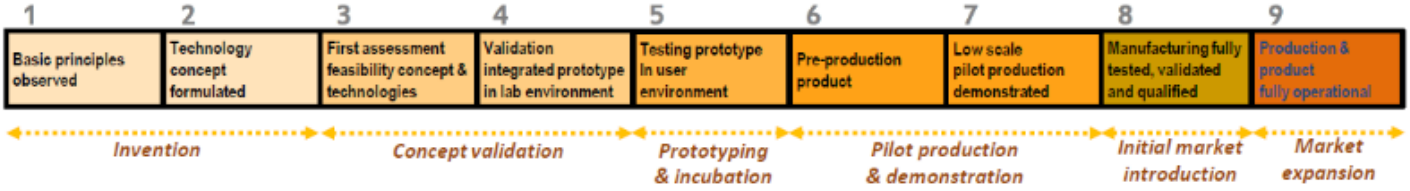
Technology readiness level

The project as of this point has met a technology readiness level of at least level 4, even pushing some level 5 criteria as defined by the European Commission[10].

Level	Definition
TRL 1.	Basic principles observed.
TRL 2.	Technology concept formulated.
TRL 3.	Experimental proof of concept.
TRL 4.	Technology validated in lab.

Level	Definition
TRL 5.	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
TRL 6.	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
TRL 7.	System prototype demonstration in operational environment.
TRL 8.	System complete and qualified.
TRL 9.	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).

The European Association of Research and Technology Organisations (EARTO) has a slightly more relevant scale of TRL[11].



The project fits this scale better and is also a level 4, with aspects of level 5 according to this scale.

Future Development

The current setup is mostly a proof of concept. For a full prototype/production model, A chip with high IO rates like a DSLR image processing chip, with a low quality and high frame rate camera with a bare LCD would be used to make the system run faster.

Because of the image processing chip it would be possible to increase the communication speed, since the IO is the limiting factor on the current setup.

The biggest IO limit at the moment is the LCD, this is because the only reasonably priced LCD's at this size that were available on the market use an SPI communication link. Also the LCD driver chip is fairly slow using this link.

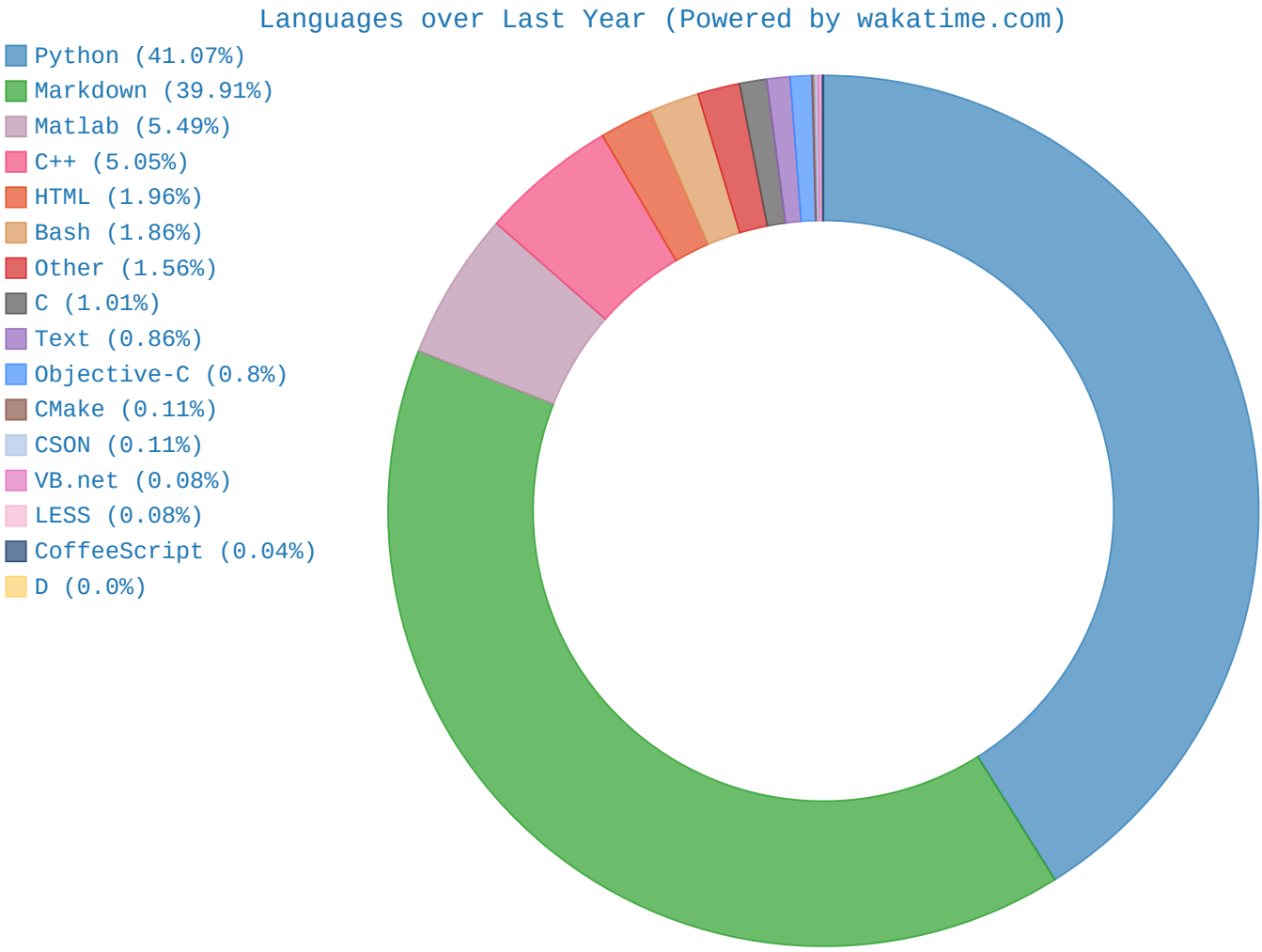
The other main issue is the fact this system assumes your eyes are always directly behind the LCD. So, for a fully fledged system it would be required that some form of simple eye tracking should be added to compensate for this.

While talking to Martin Slade about the project, one individual mentioned research which could add dynamic prescription[12]. This would be a good addition to the project as this would make the glasses truly dynamic in the sense of not needing to buy another pair of glasses in the future as, the tint and prescription can be adjusted for users.

<> By David Joseph Hawkins using **Atom** and **GitHub**

Appendix

Coding languages



Code

telegrambot.py

```
"""Telegram control file."""
import os
import subprocess
from functools import wraps
from random import choice, randint
from time import strftime

from shades import (buttonstoggle, debugset, getiso, modeset, runningstateget,
                    runningstateset, sandd, scaleFactorset, tintBackset,
                    tintShadeset)
from telegram import InlineKeyboardButton, InlineKeyboardMarkup, ParseMode
from telegram.ext import (CallbackQueryHandler, CommandHandler, Filters,
                          MessageHandler, Updater)

"""program variables"""
test_box_api_key = []
test_box = 0
user = False
admins = []
allowAll = True
jokelist = []

"""retrive telegram keys"""
try:
    f = open('telegramkeys.txt', 'r')
    test_box_api_key.append(f.readline().split('\n')[0])
    admins.append(int(f.readline().split('\n')[0]))
    f.close()
except IOError:
    print 'telgram import fail'
    exit()


"""retrive jokes"""
try:
    f = open('jokes.txt', 'r')
    for line in f:
        jokelist.append(line)
    f.close()
except IOError:
    jokelist = ['joke import failed']
    print jokelist[0]


"""Create the EventHandler and  it your bot's token."""
updater = Updater(test_box_api_key[test_box])
jbq = updater.job_queue


def restricted1(func):
    """Add re-stricter for access."""
    @wraps(func)
    def wrapped(bot, update, *args, **kwargs):
        user_id = update.effective_user.id  # get user id
```

```
        if allowAll or user_id in admins:  # if in open mode or admin id
            return func(bot, update, *args, **kwargs)  # run function
        update.message.reply_text(
            "Access denied for {}.Ask [Jo](tg://user?id={}) for access.".
            format(user_id, admins[0]),
            parse_mode=ParseMode.MARKDOWN
        )  # else echo access denied back to user
        return 'error'

    return wrapped


def restricted2(func):
    """Add re-stricter for admin only access."""
    @wraps(func)
    def wrapped(bot, update, *args, **kwargs):
        user_id = update.effective_user.id  # get user id
        if user_id in admins:  # if  admin id
            return func(bot, update, *args, **kwargs)  # run function
        update.message.reply_text(
            "Access denied for {}.Ask [Jo](tg://user?id={}) for access.".
            format(user_id, admins[0]),
            parse_mode=ParseMode.MARKDOWN
        )  # else echo access denied back to user
        return 'error'

    return wrapped


def time():
    """Return time in formated string."""
    return str(strftime('%d/%m/%Y %H:%M:%S'))


@restricted2
def spam(bot, update, args):
    """Repetitive messages for debug."""
    if int(args[0]) == 0:  # if interval = 0
        jbq.run_once(
            sendMessage, 0, context=[int(args[1]),
                                     args[2]])  # initiate job to reply
    else:  # for reppetive jobs
        jbq.run_repeating(
            sendMessage,
            interval=int(args[0]),
            first=0,
            context=[int(args[1]), args[2]])  # initiate job to repeat


@restricted2
def halt(bot, update):
    """Turn off glasses."""
    update.message.reply_text(
        'Halting at {}'
        .format(time()))  # echo that command was received
```

```
    os.system('sudo halt')  # send shutdown command


@restricted2
def reboot(bot, update):
    """Reboot glasses."""
    update.message.reply_text(
        'Rebooting at {}'
        .format(time()))  # echo that command was received
    os.system('sudo reboot')  # send reboot command


@restricted2
def allowallids(bot, update):
    """Toggle restriction level."""
    global allowAll  # pull allowAll in so function can edit

    if allowAll:  # toggle
        allowAll = False
        update.message.reply_text('allowing restricted ids.')
    else:
        allowAll = True
        update.message.reply_text('allowing all ids.')


@restricted2
def exit(bot, update, args):
    """Exit the program cleanly."""
    if len(args) >= 1:
        f = open('run.txt', 'w+')  # open file
        f.write('no')
        f.close()  # close file
    runningstateset(2)  # set sate to exit
    update.message.reply_text('Exiting at {}'
                              .format(time()))  # echo exiting back to user


@restricted2
def buttons(bot, update):
    """Toggle if the buttons are enabled."""
    buttonstoggle()
    update.message.reply_text('Toggled buttons.')  # echo toggled back to user


@restricted2
def addwifi(bot, update, args):
    """Add WiFi network."""
    ssid = args[0]
    psk = args[1]
    f = open('/etc/wpa_supplicant/wpa_supplicant.conf', 'a')  # open file
    f.write('\nnetwork={\n        ssid="')  # format and store network
    f.write(ssid)
    f.write('"\n        psk="')
    f.write(psk)
    f.write('"\n}\n')
```

```
    f.close()  # close file
    update.message.reply_text(
        'added {} to wifi'.format(ssid))  # echo added WiFi back to user


@restricted2
def scalefactor(bot, update, args):
    """Set scale factor."""
    scaleFactorset(float(args[0]))
    update.message.reply_text(
        'scale factor set to {}'.format(float(args[0])))  # echo scale factor


@restricted1
def image(bot, update):
    """Send most recent image from camera."""
    bot.send_photo(
        chat_id=update.message.chat_id, photo=open('image1.jpg',
                                                   'rb'))  # send image


@restricted1
def start(bot, update):
    """Start the glasses cleanly."""
    f = open('users.txt', 'a')  # currently debugging by logging new users
    f.write('{}\n\r'.format(update.message.from_user))
    f.close()
    runningstateset(1)  # set state to running
    update.message.reply_text('started')  # echo started back to user


@restricted1
def stop(bot, update):
    """Stop/pause glasses."""
    runningstateset(0)  # set running state to stopped
    update.message.reply_text('stopped')  # echo stopped back to user


@restricted1
def mode(bot, update, args):
    """Manually change the mode."""
    modeset(int(args[0]))  # set mode
    update.message.reply_text('mode set to {}'.format(
        args[0]))  # echo mode back to user


@restricted1
def colourset(bot, update, args):
    """Set the colour of the lenses."""
    update.message.reply_text(colorSplit(
        args[0]))  # colour information to handler


@restricted1
def autoback(bot, update):
```

```
    """Calculate the background tint in manual mode."""
    usrin = getiso()  # get ambient light level
    usrin = 'back@{},{},{}'.format(
        int(usrin), int(usrin),
        int(usrin))  # format string to be passed to handler
    update.message.reply_text(colorSplit(usrin))  # string to handler


@restricted1
def tint(bot, update, args):
    """Set background tint percentage."""
    usrin = 100 - int(args[0])  # invert percentage
    usrin = 'back@{},{},{}'.format(
        int(usrin * 2.56), int(usrin * 2.56),
        int(usrin * 2.56))  # format string to be passed to handler
    update.message.reply_text(colorSplit(usrin))  # string to handler


@restricted1
def debug(bot, update):
    """Toggle command line debug."""
    debugset()  # toggle command line debug
    update.message.reply_text(
        'debug toggled')  # echo that the debug has been toggled back to user


def uprecords(bot, update):
    """Run the uprecords command and echo results."""
    p = subprocess.Popen(
        ['uprecords', '-a'], stdout=subprocess.PIPE, stderr=subprocess.PIPE
    )  # open subprocess in thread and pipe back results
    out = p.communicate()  # collect results
    update.message.reply_text(out[0])  # echo results


def temp(bot, update):
    """Get cpu temperature."""
    temp = int(open('/sys/class/thermal/thermal_zone0/temp').read()) / 1000.0
    update.message.reply_text('CPU temperature is:{}'.format(temp))


def joke(bot, update):
    """Send a joke."""
    update.message.reply_text(choice(jokelist))  # pick random joke and send


def meme(bot, update):
    """Send a meme."""
    memeid = randint(1, 17)  # pick random image
    bot.send_photo(
        chat_id=update.message.chat_id,
        photo=open('memes/{}.jpg'.format(memeid), 'rb'))  # send image


def help(bot, update):
```

```
    """Display help menu."""
    update.message.reply_text(
        'help im stuck in a box \n\r' +
        '/pickcolour - pick from list of tints\n\r' +
        '/pickmode- pick from list of modes\n\r' +
        '/tint percentage\n\r' + '/colourset fore-back@0-255,0-255,0-255\n\r' +
        '/start starts shades\n\r' + '/stop stop shades\n\r' +
        'for more info check the [site](git.djh1997.uk)',
        parse_mode=ParseMode.MARKDOWN)


def up(bot, update):
    """Check if glasses are online."""
    update.message.reply_text('shades {} is online.'.format(test_box))


def echo(bot, update):
    """Catch all for unrecognised commands."""
    update.message.reply_text('command {} not recognised.'.format(
        update.message.text))  # echo that the command was unrecognised
    f = open('log.txt', 'a')  # log the user id and message
    f.write('{} : '.format(update.message.text))
    f.write('{}\n\r'.format(update.message.from_user))
    f.close()


def pickcolour(bot, update):
    """Inline keyboard to pick a preset colour."""
    keyboard = [[
        InlineKeyboardButton("50", callback_data=50),
        InlineKeyboardButton("80", callback_data=80),
        InlineKeyboardButton("90", callback_data=90),
        InlineKeyboardButton("100", callback_data=100)
    ], [
        InlineKeyboardButton("red", callback_data=101),
        InlineKeyboardButton("green", callback_data=102),
        InlineKeyboardButton("blue", callback_data=103),
        InlineKeyboardButton("gold", callback_data=104)
    ]]  # setup layout

    reply_markup = InlineKeyboardMarkup(keyboard)  # create keyboard

    update.message.reply_text(
        'Please choose:', reply_markup=reply_markup)  # send keyboard


def pickmode(bot, update):
    """Inline keyboard to pick mode."""
    keyboard = [[
        InlineKeyboardButton("manual", callback_data=0),
        InlineKeyboardButton("tint", callback_data=1),
        InlineKeyboardButton("point", callback_data=2),
        InlineKeyboardButton("full auto", callback_data=3),
        InlineKeyboardButton("negative", callback_data=4)
    ]]  # setup layout
```

```
    reply_markup = InlineKeyboardMarkup(keyboard)  # create keyboard

    update.message.reply_text(
        'Please choose:', reply_markup=reply_markup)  # send keyboard


def button(bot, update):
    """Create handler for inline keyboard."""
    query = update.callback_query
    tint = int(query.data)  # convert button id to int
    if tint <= 4:  # if mode button
        modeset(tint)  # set mode
        bot.edit_message_text(
            text="mode set to {}".format(tint),
            chat_id=query.message.chat_id,
            message_id=query.message.message_id)  # echo new mode
    else:  # if tint setting
        if tint <= 100:  # if standard tint
            tint = int(tint * 2.55)  # format tint
            tint = '{},{},{}'.format(tint, tint, tint)  # format tint
        elif tint == 101:  # if colour tint
            tint = '255, 200, 200'  # red
        elif tint == 102:
            tint = '200, 255, 200'  # green
        elif tint == 103:
            tint = '200, 200, 255'  # blue
        elif tint == 104:
            tint = '255, 223, 0'  # gold
        bot.edit_message_text(
            text="Selected option: {}".format(
                colorSplit('back@{}'.format(tint))),
            chat_id=query.message.chat_id,
            message_id=query.message.message_id)  # set tint and echo result


def colorSplit(usrin):
    """Colour handler."""
    error = False
    usrin = usrin.split('@')  # split colour and location
    tint = usrin[1].split(',')  # split colours
    reply = ''
    for i in range(len(tint)):  # iterate over rgb values
        tint[i] = int(tint[i])  # convert to int
        if tint[i] not in range(0, 257):  # check value is in valid range
            reply = 'rgb out of range'  # warn user of error
            error = True  # trigger error
    if error is False:  # if all values in spec
        if usrin[0] == 'back':  # set background tint
            tintBackset(tint)  # data to handler
            reply = tint  # echo back the rgb values
        elif usrin[0] == 'fore':  # set foreground tint
            tintShadeset(tint)  # data to handler
            reply = tint  # echo back the rgb values
        else:  # if not fore or back warn user and show formatting
```

```
            reply = 'valueError format like this fore-back@0-255,0-255,0-255'
    return reply


def sendMessage(bot, job):
    """Send message handler for job_queue."""
    bot.send_message(chat_id=job.context[0], text=job.context[1])


def telegramMain():
    """Telegram main function."""
    global updater

    # Get the dispatcher to register handlers
    dp = updater.dispatcher

    # on different commands - answer in Telegram
    # all
    dp.add_handler(CommandHandler("help", help))
    dp.add_handler(CommandHandler("uprecords", uprecords))
    dp.add_handler(CommandHandler("up", up))
    dp.add_handler(CommandHandler("temp", temp))
    dp.add_handler(CommandHandler('joke', joke))
    dp.add_handler(CommandHandler('meme', meme))

    # togglable
    dp.add_handler(CommandHandler("start", start))
    dp.add_handler(CommandHandler("stop", stop))
    dp.add_handler(CommandHandler("mode", mode, pass_args=True))
    dp.add_handler(CommandHandler("autoback", autoback))
    dp.add_handler(CommandHandler("tint", tint, pass_args=True))
    dp.add_handler(CommandHandler("colourset", colourset, pass_args=True))
    dp.add_handler(CommandHandler('pickcolour', pickcolour))
    dp.add_handler(CommandHandler('pickmode', pickmode))
    dp.add_handler(CommandHandler('image', image))
    dp.add_handler(CommandHandler('debug', debug))

    # admins only
    dp.add_handler(CommandHandler("exit", exit, pass_args=True))
    dp.add_handler(CommandHandler('spam', spam, pass_args=True))
    dp.add_handler(CommandHandler('allowallids', allowallids))
    dp.add_handler(CommandHandler("halt", halt))
    dp.add_handler(CommandHandler("reboot", reboot))
    dp.add_handler(CommandHandler("buttons", buttons))
    dp.add_handler(CommandHandler("addwifi", addwifi, pass_args=True))
    dp.add_handler(CommandHandler("scalefactor", scalefactor, pass_args=True))

    # keyboard handler
    dp.add_handler(CallbackQueryHandler(button))

    # on noncommand i.e message - echo the message on Telegram
    dp.add_handler(MessageHandler(Filters.text, echo))
    dp.add_handler(MessageHandler(Filters.command, echo))

    # Start the Bot
```

```
    updater.start_polling()

    # Run the bot until you press Ctrl-C or the process receives SIGINT,
    # SIGTERM or SIGABRT. This should be used most of the time, since
    # start_polling() is non-blocking and will stop the bot gracefully.
    jbq.run_once(sendMessage, 0, context=[
                admins[0], 'Shades booting at {}'.format(time())])
    while runningstateget() != 2:
        if runningstateget() != 1:
            runningstateset(1)
            sandd()
    # updater.idle()
    updater.stop()


telegramMain()
```

shades.py

```
"""Pi0to chromic control file."""
import os
from time import sleep, time

import Adafruit_GPIO.SPI as SPI
import ST7735 as TFT
from gpiozero import Button
from picamera import PiCamera  # camera
from PIL import Image
from skimage.feature import blob_doh  # blob detection
from skimage.io import imread  # convert jpg to np array

"""screen variables"""
WIDTH = 128
HEIGHT = 160
SPEED_HZ = 125000000

scaleFactor = .25

"""Raspberry Pi configuration."""
DC = 24
RST = 25
SPI_PORT = 0
SPI_DEVICE = 0

"""program variables"""
processpoint = [['clear', 'display'], ['autoback', 'clear', 'display'], [
    'take', 'convert', 'blob find', 'blob to point', 'clear', 'point maths',
    'display'
], [
    'autoback', 'take', 'convert', 'blob find', 'blob to point', 'clear',
    'point maths', 'display'
], ['take', 'display']]
averageFps = []
running = 0
tintShade = [32, 32, 32]
tintBack = [256, 256, 256]
tintbuttonvar = 255
mode = 0
debug = 0
disp = 0
draw = 0
camera = 0
buttons = 1
new = True

"""button connection"""
buttonTint = Button(2)
buttonMode = Button(3)
buttonDebug = Button(4, hold_time=5)
"""buttonReset = Button(14, hold_time=2)
buttonexit = Button(15, hold_time=5)"""
```

```
def initlcd():
    """Initilize the lcd's."""
    global disp, draw
    print 'initializing LCD'
    disp = TFT.ST7735(
        DC,
        rst=RST,
        spi=SPI.SpiDev(SPI_PORT, SPI_DEVICE,
                       max_speed_hz=SPEED_HZ))  # setup SPI port
    disp.begin()  # start screen class
    disp.display(
        Image.open('pi0toChroma.jpg').rotate(270).transpose(
            Image.FLIP_TOP_BOTTOM).resize((WIDTH,
                                           HEIGHT)))  # draw splash screen
    draw = disp.draw()  # put splash screen on LCD's
    print 'LCD initialized'


def deinitlcd():
    """Deinitilise the lcd."""
    global disp
    disp.display(Image.open('close.jpg').rotate(90).resize(
        (WIDTH, HEIGHT)))  # display close screen
    sleep(.5)
    disp.clear((256, 256, 256))  # set LCD to clear
    disp.display()
    print 'LCD cleared'


def initcamera():
    """Initilize the camera."""
    global camera
    print 'initializing camera'
    camera = PiCamera()  # open camera
    camera.color_effects = (128, 128)  # set camera to grey scale
    camera.resolution = (int(160 * scaleFactor),
                         int(128 * scaleFactor))  # set resolution to screens
    camera.rotation = 270  # correct orinetation
    camera.vflip = True
    if debug == 1:  # if debug was called before camera initialization was run
        camera.start_preview()  # start camera preview
    sleep(3)  # wait for camera to stabilise
    print 'camera initialized'


def deinitcamera():
    """Disconnect camera so the next instance of the program can access."""
    global camera
    camera.close()
    print 'camera closed'


def scaleFactorset(newsf):
    """Change the scake factor."""
    global scaleFactor
```

```
    scaleFactor = newsf
    camera.resolution = (int(160 * scaleFactor),
                         int(128 * scaleFactor))  # set resolution to screens


def debugset():
    """Toggle debug."""
    global debug
    if camera != 0:  # check if camera initialization has been run
        if debug == 0:  # toggle preview
            camera.start_preview()
        else:
            camera.stop_preview()
    else:
        # if camera initialization hasn't  been run print warning
        print 'camera not defined yet'

    debug ^= 1  # toggle debug
    if debug == 1:  # print new debug state
        print 'debug on'
    else:
        print 'debug off'


def runningstateset(state):
    """Set running state."""
    global running
    # try:  # try assuming state is a button
    #     if state.pin.number == buttonReset.pin.number and state.is_held:
    #         state = 1  # set state to running
    #     elif state.pin.number == buttonReset.pin.number:
    #         state = 0  # set state to stopped
    #     elif state.pin.number == buttonexit.pin.number and state.is_held:
    #         state = 2  # set state to exit
    # except AttributeError:  # catch not button error
    #     print 'not button'  # print warning
    print 'state ' + str(state)  # print new state
    running = state  # set state


def tintShadeset(tint):
    """Set Shade tint."""
    global tintShade
    tintShade = tint  # set tint level for active shade points


def autoshadeset(tintdifference):
    """Set shade point tint unsing background and difference."""
    global tintShade
    for i in range(len(tintShade)):
        tintShade[
            i] = tintBack[i] - tintdifference  # set tint difference points


def tintBackset(tint):
```

```
    """Set background tint."""
    global tintBack, new
    tintBack = tint  # set tint level for background
    new = True


def tintButton(buttonTint):
    """Set the background tint based on button presses."""
    global tintBack, tintbuttonvar
    if buttonTint.is_held or tintbuttonvar < 64:  # if button is held reset
        tintbuttonvar = 256  # set tint to clear
    elif tintbuttonvar >= 64:  # increment tint if not at limit
        tintbuttonvar -= 64
    tintBackset([tintbuttonvar, tintbuttonvar, tintbuttonvar])  # set tint
    print tintBack


def modeset(modevar):
    """0 manual 1 tint 2 point 3 auto 4 negative."""
    global mode, averageFps, new
    try:  # try assuming modevar is a button
        if modevar.pin.number == 3 and modevar.is_held:
            modevar = 0  # reset mode to manual
        elif modevar.pin.number == 3:
            if mode >= 4:  # if at limit the reset to manual
                modevar = 0
            else:  # else increment
                modevar = mode + 1
    except AttributeError:  # catch not button error
        print 'not button'  # print warning
    if modevar == 4:
        camera.hflip = True
        camera.image_effect = 'negative'
    else:
        camera.hflip = False
        camera.image_effect = 'none'
    mode = modevar  # set mode
    averageFps = []  # reset average fps array
    tintBackset([256, 256, 256])
    tintShadeset([32, 32, 32])
    new = True
    print 'mode ' + str(mode)  # display new mode


def runningstateget():
    """Return current state."""
    global running
    return running


def getiso():
    """Get iso level of sensor.."""
    global camera
    maxtint = 4
    iso = float(camera.analog_gain)  # get current ambient brightness 0..8
```

```
    iso = (iso * maxtint)  # adjust buy max tint level
    iso = (256 - (maxtint * 8)) + iso  # clear - max tint + ISO tint
    return int(iso)


def halt():
    """Halt the system."""
    os.system('sudo halt')  # send halt command to terminal


def initbuttons():
    """Initilize buttons.

    Wait for all button to be released
    Then asign to correct function.
    """
    print 'initializing butoons'
    buttonTint.wait_for_release(
    )  # wait incase any of the buttons are locked high
    buttonMode.wait_for_release()
    buttonDebug.wait_for_release()
    # buttonReset.wait_for_release()
    # buttonexit.wait_for_release()
    buttonTint.when_pressed = tintButton  # set button state to function
    buttonTint.when_held = tintButton
    buttonMode.when_pressed = modeset
    buttonMode.when_held = modeset
    buttonDebug.when_pressed = debugset
    # buttonDebug.when_held = halt
    # buttonReset.when_pressed = runningstateset
    # buttonReset.when_held = runningstateset
    # buttonexit.when_held = runningstateset
    print 'buttons initialized'


def deinitbuttons():
    """Deinitilize buttons.

    Release button from function.
    """
    print 'Deinitializing buttons'
    buttonTint.when_pressed = None  # set button state to function
    buttonTint.when_held = None
    buttonMode.when_pressed = None
    buttonMode.when_held = None
    buttonDebug.when_pressed = None
    # buttonDebug.when_held = None
    # buttonReset.when_pressed = None
    # buttonReset.when_held = None
    # buttonexit.when_held = None
    print 'Deinitilized buttons'


def buttonstoggle():
    """Toggle buttons."""
```

```
    global buttons
    buttons ^= 1
    if buttons == 0:
        deinitbuttons()
    else:
        initbuttons()


def sandd():
    """Pi0t0 chromic main function.

    This handles the main running of the shades.
    This is done by having nested while loops to control different states.
    Then there is if statments to control weather the system reactes to the
    camera or not, and how to update the lenses
    """
    global averageFps, new
    initlcd()  # initialize peripherals
    initbuttons()
    initcamera()
    while running != 2:  # exit state
        while running == 1 and new:  # running state and new
            timer = []  # reset internal variables
            points = []
            modeinternal = mode

            if (modeinternal == 1) or (
                    modeinternal == 3):  # if mode with auto background tint
                timer.append(time())  # add timer point
                ti = getiso()  # get light level
                tintBackset([ti, ti, ti])  # calculate background tint
                if modeinternal == 3:
                    autoshadeset(ti)

            if modeinternal >= 2:  # if camera mode
                timer.append(time())  # add timer point

                camera.capture(
                    'image1.jpg', use_video_port=True,
                    thumbnail=None)  # capture image

            if modeinternal == 4:  # if negative mode
                timer.append(time())  # add timer point
                disp.display(Image.open('image1.jpg').rotate(90).resize(
                    (WIDTH, HEIGHT)))  # display image

            if (modeinternal == 2) or (modeinternal == 3):  # if point shading
                timer.append(time())  # add timer point
                img1 = imread('image1.jpg', as_grey=True)

                timer.append(time())  # add timer point
                blobs_doh = blob_doh(
                    img1, max_sigma=15, threshold=.0075)  # find blobs

                timer.append(time())  # add timer point
```

```
        for i in range(len(blobs_doh)):  # calculate points from blobs
            points.append([
                blobs_doh[i][0] / scaleFactor,
                blobs_doh[i][1] / scaleFactor,
                (blobs_doh[i][1] / 3) / scaleFactor, tintShade
            ])  # x,y,r,tint

    if modeinternal <= 3:  # not negative mode
        timer.append(time())  # add timer point

        disp.clear((tintBack[2], tintBack[1],
                    tintBack[0]))  # set background tint

    if (modeinternal == 2) or (modeinternal == 3):  # if point shading
        timer.append(time())  # add timer point
        for i in range(0,
                       len(points)):  # convert x,y,r to bounding box
            x1 = int(points[i][0] - points[i][2])
            x2 = int(points[i][0] + points[i][2])
            y1 = int(points[i][1] - points[i][2])
            y2 = int(points[i][1] + points[i][2])
            draw.ellipse(
                (x1, y1, x2, y2),
                fill=(points[i][3][2], points[i][3][1],
                      points[i][3][0]))  # draw

    if modeinternal <= 3:  # not negative mode
        timer.append(time())  # add timer point
        disp.display()  # put the drawing on the the LCD's

    timer.append(time())  # add timer point

    if modeinternal == 0:  # if in mode 0 then toggle new
        new = False
    else:
        new = True

    if debug == 1:  # if debug is on the print timings

        print 'number of points: {}\n'.format(len(points))
        print 'points:{}\n'.format(points)
        print 'background tint: {}\n'.format(tintBack)
        print 'foreground tint: {}\n'.format(tintShade)
        for t in range(0,
                       len(timer) -
                       1):  # iterate over timing list to get timings
            print 'function {} : time {}\n'.format(
                processpoint[modeinternal][t],
                timer[t + 1] - timer[t])  # print function and time

        totaltime = timer[len(timer)
                          - 1] - timer[0]  # calculate total time
        averageFps.append(1 / totaltime)  # calculate fps and append
        if len(averageFps) >= 11:  # buffer has min number of values
```

```
                    if len(averageFps) >= 61:  # buffer full then remove oldest
                        averageFps.pop(0)
                    print 'average fps = {: 4.2f}\n'.format(
                        sum(averageFps) / len(averageFps))  # print average fps
                print 'total = {: 4.2f}  fps = {: 4.2f}\n'.format(
                    totaltime, averageFps[len(averageFps)
                                          - 1])  # print total time and fps

        sleep(1)

    deinitlcd()  # close peripherals
    deinitcamera()
```

1. https://youtu.be/E5d7ynJXiZc?t=4m32s ↩
2. https://www.ibuypower.com/Signature/Snowblind ↩
3. http://www.e-tintproducts.com ↩
4. http://www.e-tintproducts.com/technology/ ↩
5. http://www.e-tintproducts.com/ctrl-eyewear/ ↩
6. https://picamera.readthedocs.io/ ↩
7. https://github.com/cskau/Python_ST7735 ↩
8. https://dle.plymouth.ac.uk/mod/resource/view.php?id=328795#page=5 ↩
9. http://scikit-image.org/ ↩
10. https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf ↩
11. http://www.earto.eu/fileadmin/content/03_Publications/The_TRL_Scale_as_a_R_I_Policy_Tool_-_*EARTO_Recommendations*-_Final.pdf#page=7 ↩
12. https://www.ttp.com/case-studies/electronic_lenses ↩