THE USE OF COLOUR TO DETERMINE THE POSITION OF A POINTER ON A SCREEN

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Abstract

Thin Film Transistor (TFT) screens are becoming more common in the workplace, replacing traditional Cathode Ray Tube (CRT) screens. As the TFT screen does not generate a scan line, traditional methods of light sensing pens do not work effectively on a TFT screen. This paper describes a novel light pen type peripheral, which may be used on either a TFT or CRT screen. The peripheral is intended to replace the need to use a touch screen, mouse or keyboard. A specially designed kaleidoscope is placed on the screen; these colours are then detected using a tri-colour photodiode. The output from the sensor is filtered and transmitted via a link to the computer; the computer then translates the colour into a corresponding co-ordinate on the screen.

The Hardware

Intuitive touch interfaces are used in a variety of markets [1] and applications to decrease training times, increase productivity, create higher quality products and services, and raise profits. From mainstream applications in retail stores, restaurants, supermarkets, banks, schools, casinos, and medical facilities, to more complex applications in process control, military command, emergency call centres (911 or 999) and air traffic control. Touch-enhanced displays put the power of information at people's fingertips.

In dirty environments such as garages, 'mice and keyboards' suffer due to grease and dirt getting into their mechanisms [2]. Touch Screens are impractical when the touch screen is subjected to sharp edges, which can cause damage, for example a ballpoint pen. Some users already started using pens long before they were introduced to 'keyboards and mice'; it is therefore logical that users will interact better with a stylus than they would other peripherals.

Touch screens that use stylus are one alternative to 'keyboards and mice' that have remained static in the marketplace for a number of years. Hazardous environmental problems have been overcome whilst users have the advantage that they can use the stylus whether they are right or left-handed. Problems arise with touch screens due to the cost of installation and difficulties transferring between computers.

Installation of touch screens has been expensive as Visual Display Units (VDUs), have different curvatures, size, etc; therefore a large product range is required. Conversely it is also difficult to replace a touch screen when damaged, as the VDU needs to be dismantled.

Alternative peripherals to touch screens were investigated which offer similar advantages, one such peripheral is a light pen. The light pen works by detecting the CRT scan line, utilising a photosensitive diode installed into the light pen to detect the refresh of the screen [9]. This method is optimised for CRT screens.

A Cold Cathode Florescent Tube (CCFT) illuminates the TFT screen so no scan line is produced, therefore traditional light pens would not work on these screens. A new method of using colour to determine the region of the screen that was being pointed to was investigated. This new device can be used on either a TFT screen or a CRT screen. This would reduce installation costs, increase durability and would also be transferable between computers.

A possible solution would be to display a kaleidoscope of colours on the VDU that could be detected by a colour sensor. This would then be used to determine the location on the screen at which the sensor was pointing.

Mazet Colour Sensor (MCS)

A MCS3AT tri-colour photodiode sensor [3] is shown in figure 1. This sensor was selected to detect colours displayed on a VDU because of its small size and claimed accuracy at differentiating colours.

Figure 1: MCS3AT Colour Sensor.

The circuit in figure 2 was built to convert the photocurrent to an equivalent voltage, using suggested resistor values (from [4]). This was then used to probe a CRT screen, to detect red, green and blue. A current meter was used to read the outputs from each of the sensor outputs and results are recorded in table 1.

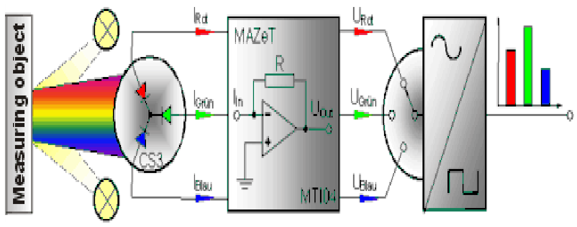

Figure 2. Circuit to convert photocurrent to an equivalent voltage.

Colour	**Current (μA)**	**Resistance (KΩ)**
Red	180	25
Green	8	500
Blue	0.8	5000

Table 1. Sensor characteristics

The circuit shown in figure 2 was used to detect the same red, green blue colours on a TFT screen, a sinatoidal wave appeared to be added to the received signal with a period of around 30μS. It was thought that the CCFT, which was used to provide backlight to the TFT, caused this. The characteristic of the CCFT [5] is given in table 2.

LCD timing characteristics which may affect the output signal are given in table 3 (from [5]). This differs from the output to the CRT screen, which is updated every 60 Hz (16.6ms).

A lux meter was used to obtain the brightness of a TFT screen and CRT screen. This was coupled together with the circuit shown in figure 2 was built this was used to detect colours on a CRT screen; the results are shown in figure 3.

Parameter	**KHz**	**KHz**	**KHz**	**μS**
Lamp Current	2mA	6mA	6.5mA	
Power Consumption		3.3W		
Lamp Frequency	20	35	60	16
Kick off Voltage		1200V	1400V	(@0°C)
Lamp Lifetime		30,000hr		

Table 2: Lamp Characteristics

Parameter		**Min**	**Typical**	**Max**	**Unit**
Clock	Frequency		40	42	MHz
	High time	5			Ns
	Low time	5			Ns
	Duty ratio	40	50	60	%
Data	Set time	3			Ns
	Hold time	10			Ns
Horizontal Sync. Signal	Cycle	20.8	26.4		μS
	Pulse Width	2	128	200	Clock
Vertical Sync. Signal	Cycle	628	666	789	Line
	Pulse Width	2	4	6	Line
Horizontal display period		800	800	800	Clock
Vertical display period		23	23	23	Line

Table 3: LCD timing characteristics

Experiment to determine ability of MCS to detect colour

As the output of the sensor was low, a 100K and a 1MΩ resistor were used on the red op-amp increasing the gain by a factor of 10 (shown in figure 4 and 5). This increased the area detected by the sensor on a TFT screen.

An experiment was devised to test the reliability of the sensor. The TFT was emulated using a tube with a length of 15” (38.1 cm) was assembled so that a bulb would displace the light over a 4” square lens.

When the sensor with modified resistor values was used to detect colour on a TFT screen, only noise was detected.

It was believed the CCFT voltage doubler circuit (kick off voltage in table 2) caused the problems. To prove this, a laptop was placed into an EMC chamber and the results are shown in figures 6 and 7.

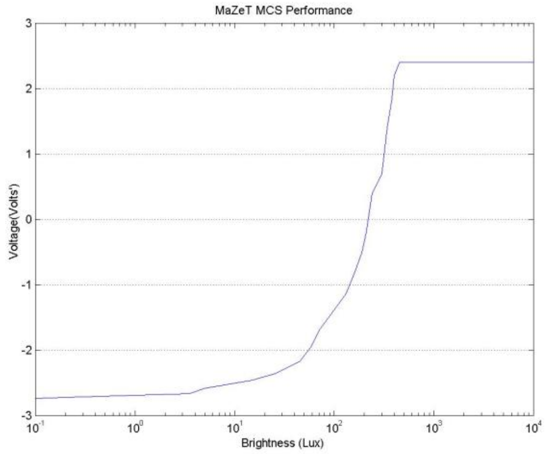

Figure 3: A CRT monitor has a lux value around 110, whereas a laptop TFT monitor is around 34.

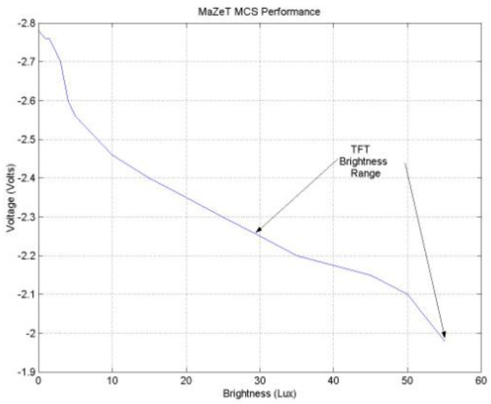

Figure 4: A 100KΩ resistor used, on the red output.

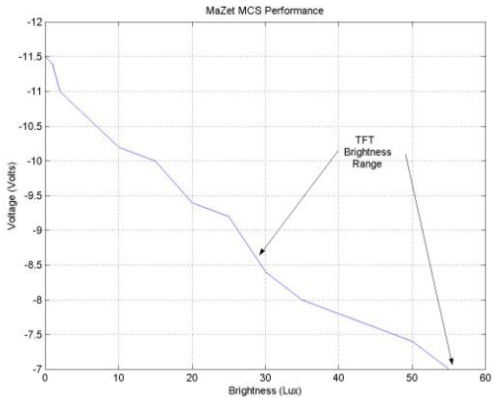

Figure 5 : A 1MΩ resistor used, on the red output.

Figure 6 and figure 7 show that EMC emissions are greater at the bottom of the TFT screen. There were two frequencies that appeared constant on the right hand side of the screen: *38 MHz* and *60 MHz*. These frequencies are in similar to CCFT power circuit, given in table 3.

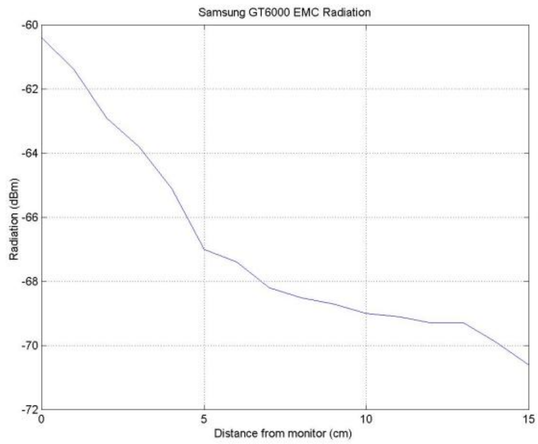

Figure 6 : EMC Radiation from a Samsung monitor.

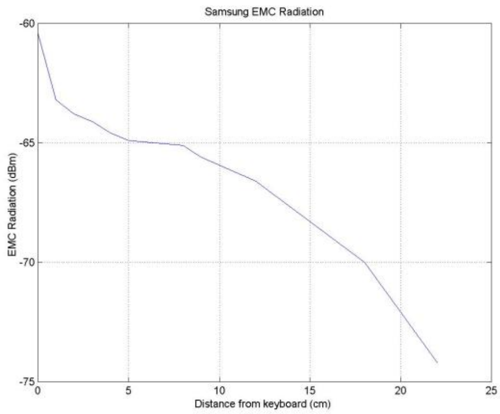

Figure 7: Radiation Vertically from the keyboard

Filter Design

Figure 8 shows the MCS response to different colours (taken from [3]). The sensor already filtered infrared frequencies but did not filter any lower end frequencies (ultraviolet frequencies etc). There is also crossover between each of the colours, in particular green crosses into red and blue. To enhance the amplified range, a filter circuit was added to the op-amp. In addition, stray wavelengths may have existed in the lab environment and to help structure the each sensor better, a filter was designed to remove everything in blue. Calculations are shown below.

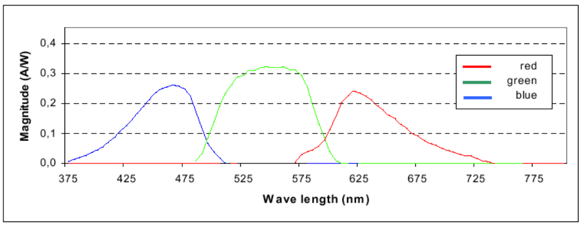

Figure 8: MCS Sensitivity.

It is possible to add a filter capacitor into the circuit, to remove a certain frequency using equation 1(from [6]).

$$f = \frac{1}{4RC}$$

$$C = \frac{1}{4Rf}$$

Equation 1: CR Equation.

Adding values to these equations, if R = 220K and f = 5 KHz then:

$$\frac{1}{4 \times 22 \times 10^{4} \times 5 \times 10^{3}} = 2.5 \times 10^{-10} \text{ or 25nF.}$$

Initial Colours. From the initial designs, the data in table 4 was gathered on the sensors' ability to determine colour on a TFT screen.

Hue Saturation and Brightness. A problem with the RGB model was that it did not compensate for the brightness of the VDU. Another model that considered Hue, Saturation and Brightness was investigated as values of hue and saturation were unaffected by brightness. In certain situations it was beneficial to have varying levels of brightness, for example in emergency vehicles at night time the on board computers should be dimmer so as not to distract the driver. Saturation and brightness were modelled on a circle, with the centre of the circle being 100% saturation – white. In the z-axis, this may be thought of brightness, illustrated in figure 9.

Figure 9 HSB cone.

The HS levels detected by the sensor are in table 5.

No.	RED	GREEN	BLUE	COLOUR
0	178-181	141-143	159-163	White
1	175-182	116-120	106-109	Yellow
2	147-151	76-78	134-137	Purple
3	143-145	51-54	82-87	Red
4	120-125	125-130	139-142	Cyan
5	110-113	100-102	85-86	Green
6	90-92	62-64	117-120	Blue
7	96-101	42-45	74-77	Grey
8	115-117	73-76	105-107	Light Grey
9	106-110	40-42	68-75	Brown
10	102-104	46-48	94-99	Light Purple
11	98-101	33-37	64-67	Light Red
12	89-93	69-74	97-104	Light Blue
13	81-86	55-60	64-66	
14	63-69	36-40	79-82	Light Green
15	57-60	21-23	43-46	Black

Table 4 RGB detected levels.

No.	Hue	Saturation	COLOUR
0	38-50	0.19-0.2	White
1	73-75	1.20 – 1.30	Yellow
2	63	0.58	Purple
3	322-328	0.7-0.6	Red
4	117	1.49	Cyan
5	24-26	1.112	Green
6	0.8-1.0	0.86	Blue
7	126-130	0.38-0.5	Grey
8	96-109	0.08-0.09	Light Grey
9	114-117	1.48-1.52	Brown
10	158-169	0.76-0.85	Light Purple
11	125-	1.86	Light Red
12	309	0.375	Light Blue
13	42-48	0.76-0.8	
14	236-237	0.82-0.89	Light Green
15	117-120	1.0-1.10	Black

Table 5: HSB detected levels.

This was grouped together to show the results in figure 9 showing distribution.

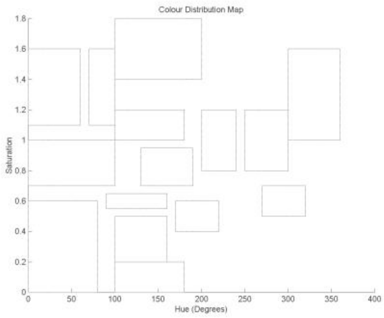

Figure 9: HSB Colour Distribution

High pass filter

An op amp capable of filtering signals [7] was used to determine suitable values of Z3 and Z2 to filter frequencies less than 100Hz, as a refresh of 65Hz was common for most computers. (as given in equation 2).

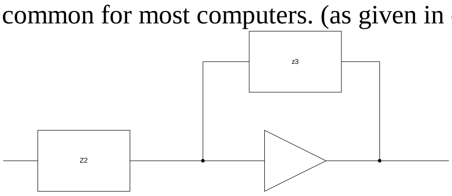

Figure 10: High Pass Filter

$$f_{23} = \frac{1}{2\pi C_{in} R_{in}}$$

$$\therefore C_{in} = \frac{1}{2\pi f_{23} R_{in}}$$

$$C_{in} = \frac{1}{2\pi f_{23} R_{in}}$$

$$C_{in} = \frac{1}{2\pi \times 100 \times 50 \times 10^3}$$

Equation 2: Capacitor filtering on an op-amp

Taking R_{in} to be 50KΩ, a value of 33nF was used to act as a suitable high pass filter.

$$Z_3 = \frac{1}{C + \frac{1}{R}}$$ *Equation 3: Op-amp gain*

Using the equation 3, the gain was reduced to 49.917, rather than 50 so that it remained unaffected.

Data Acquisition

A data acquisition board [10] was used to interface the sensor to the PC. A program that displayed a colour grid on a screen was written to display the detected HSB values. Figure 10 shows the results and a program then converted the value back to a corresponding x, y position.

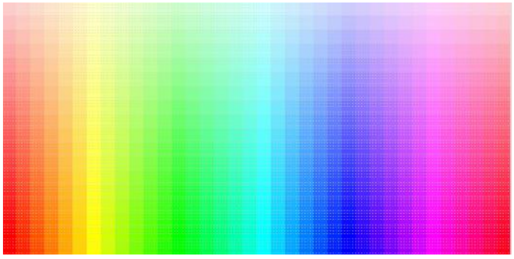

Figure 11: HSB kaleidoscope

The Mazet Sensitivity to Colours

Problems occurred with hue and saturation. After some saturation levels the hue changed and a saturation limit (sl) was reached so that colours were too saturated for detection. It was proposed that using a square would be a beneficial solution, as the calculations are reduced.

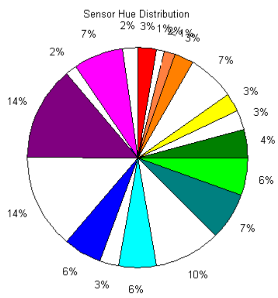

Figure 12: Colour sensitivity

The distribution of colours is shown in figure 12. Yellow overlapped with both green and orange. Each colour was a pie slice to avoid overlapping. The proposed square was placed on the circle and colours divided accordingly as shown in figure 13.

To calculate the efficiency of this method, consider the HS colour model as a complete circle, with the detected area a square in the middle (shown in figure 13); the difference in area is the efficiency. The area detected was calculated using Pythagoras theorem so that the radius of the colour wheel equalled the shorter sides.

The hypotenuse is equal to $\sqrt{r^2 + r^2}$ so the area detected by the sensor was equal to equation 4.

$$\sqrt{r^2 + r^2} \times \sqrt{r^2 + r^2} = 2r^2$$

Equation 4: Modification of Pythagoras' theorem.

The ratio of lost area = $\frac{2r^2}{\pi r^2}$ and cancelling r^2 gives

$$\frac{2}{\pi}$$

Assuming the radius r (the hue) =1, the saturation limit = 0.15, then the area available to the square is:

$$A = 2r^2 - \pi r^2$$
$$A = 2 - \pi \times 0.15^2$$
$$A = 2 - 0.0225\pi$$
$$A = 1.92$$

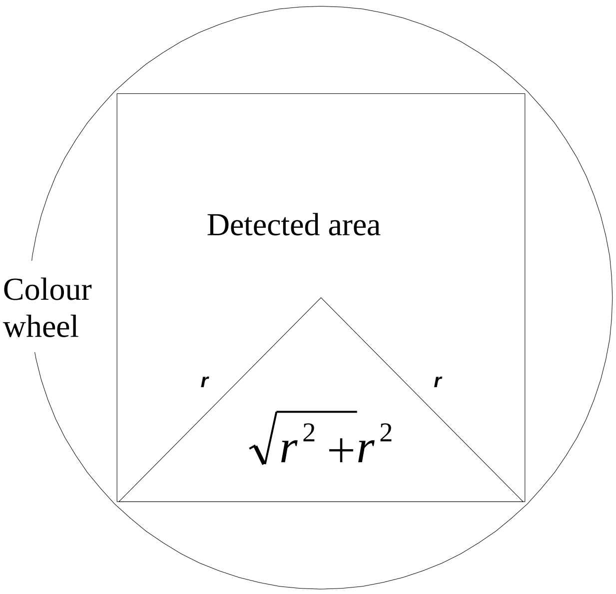

Figure 13: Distribution of colours

The area of a circle, with sl of 0.15 taken out would be:

$$A = \pi r^2 - \pi sl^2$$
$$\therefore A = \pi(r^2 - sl^2)$$
$$A = \pi(1 - 0.0225)$$
$$A = 0.9775\pi$$
$$A = 3.07$$

Ratio of detected area of the colour wheel is:

$$\frac{1.92}{3.07} \approx 3/5 .$$

Conclusion

The VDU and internal components of computer systems have evolved; input peripherals such as the keyboard and mouse have been left behind.

Figure 14 shows areas of the project to be overcome.

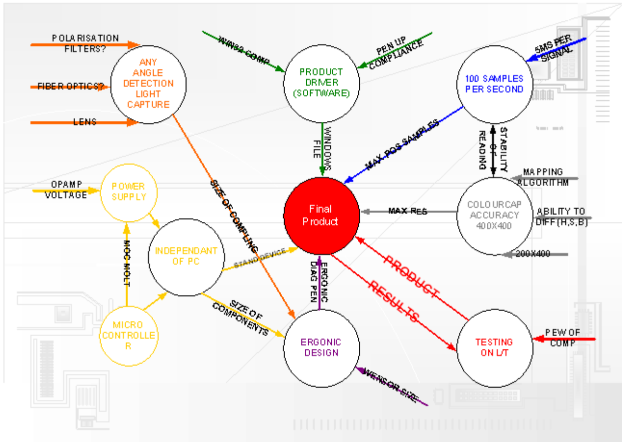

Figure 14: Project Obstacle DFD

From this the principle requirement is the devices ability to differentiate 400x400 colours. As it can be seen the device was unable to differentiate more the 28 colours.

This is the critical path of the project, as this goal could not be met, the research was abandoned. A method employing an ANN architecture is currently being investigated.

References

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