Pointer device for thin-film transistor and cathode ray tube computer screens

D.A. Sanders, S.D. Urwin-Wright, G.E. Tewkesbury and B. Gremont

A system is described that depicts where a user is pointing on either a CRT or TFT computer screen. The system uses a kaleidoscope of colours flashed onto the screen around a colour sensor at a speed that is not registered by a human user. This is made possible by using an artificial neural network (ANN) to predict the next pointer position of the sensor on the screen.

Introduction: A common intuitive touch interface is the light pen [1], which works by detecting a cathode ray tube (CRT) scan-line using a photosensitive diode. Traditional light pens will not operate on modern luminescent backlight thin-film transistor (TFT) screens as they do not produce scan-lines. As a novel alternative, colour sensors have been investigated for use in pointing at computer screens [2]. The sensors were not capable of detecting position as they could not detect colours quickly or accurately enough. The novel solution described in this Letter involves intermittently displaying a kaleidoscope of colours on a screen. The output from this system is then converted into a co-ordinate and used to move a cursor.

Method: A tri-colour photodiode is sampled and a mean is calculated over five readings. If the calculated (x, y) position is invalid then the kaleidoscope of colours is shuffled and redisplayed so that the tri-colour photodiode is located without the colours remaining on the screen for too long. Displaying re-iterations of the kaleidoscope increases the time to return an accurate location so an artificial neural network (ANN) predicts future positions and places optimum colours close to the photodiode. This allows the kaleidoscope to change colours and size to ensure an accurate detection of the position. If the sensor is not detected, because the pen is removed from the screen for example, then a full kaleidoscope of colours is displayed briefly until the sensor is relocated.

Colour detection: The sensor processing system is the novel application rather than the sensor itself. A lower specification tri-colour photodiode sensor was selected, the Mazet MCS3AT [3]. The raw sensor was 25 mm wide. Accuracy and resolution can be improved to an individual pixel with simple optics and CCD technology but to prove the method a raw sensor was used. The area that the raw sensor detected was 10 mm^2 and each colour location was made slightly larger at 15 mm^2. With the dynamic kaleidoscope, the raw sensor was made accurate to less than 5 mm^2 but was further improved with a dynamic refresh of the kaleidoscope under the sensor. The sensor detected colour as red green blue (RGB) [4] but did not compensate for the brightness of the screen. As a consequence, another model that considers hue, saturation and brightness (HSB) [4] is used as the values of hue and saturation are unaffected by brightness. The HSB colour diagram can be modelled with the centre of a circle being 100% saturation (white) and the z-axis represents brightness. Saturation is the radius of the circle and hue varied with the angle. A two-dimensional colour scheme was established for hue and saturation, as brightness was no longer a factor to be considered. With constant brightness, the HSB model can be represented as a series of colour wheels with varying saturation levels. Hue is measured in degrees around the circle and saturation is represented by the radius of the circle. Colour wheels were plotted using the tri-colour photodiode on various screens [2] and they suggested that the photodiode was not always able to detect colour correctly on a TFT screen. This new system was created to display a dynamic kaleidoscope of the optimum colours closest to the sensor or its future location, thereby allowing a reduction of the area of the screen needed to display the kaleidoscope. Furthermore, shuffling the kaleidoscope was not always necessary because the optimum colours were already close to the pen and this reduced the time spent searching for the photodiode.

Artificial neural network (ANN): ANNs have been used in control and prediction problems [5, 6]. Their ability to capture and model information from nonlinear systems and to generalise information from learned data makes them suitable for colour prediction. The proposed solution uses a feed-forward neural network (FFNN) trained using a back-propagation supervised training algorithm. The architecture is shown in Fig. 1. The first operation consists of converting the RGB signal into HSB using a simple conversion algorithm. The RGB signal is passed through an A to D converter to the PC. The PC converts this into a HSB value and uses a look-up table to convert it into an (x, y) co-ordinate. This co-ordinate is fed into an ANN used to update the future position of the screen cursor. The reformat grid then places the most responsive colours closest to the pen (according to the prediction). The data inputs to the FFNN are based on current (x, y) co-ordinates and the previous two co-ordinates. A typical 14-inch TFT screen for example, needs approximately 108 locations to be differentiated. During testing, this data was formatted into previous point and next point and split into training and testing inputs, the total sample size being 15 000 points.

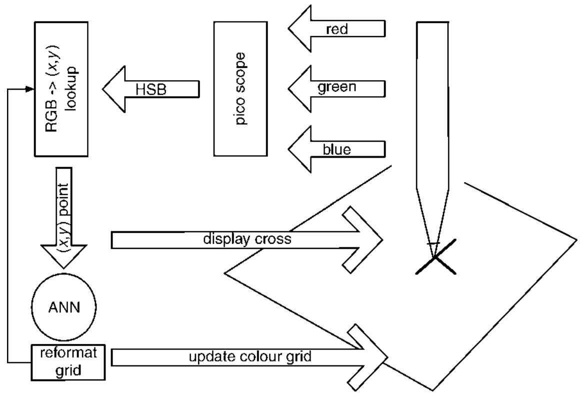

Fig. 1 *Unit architecture*

Results: The number and arrangement of input and hidden layer neurons was increased until the prediction error did not reduce further. As a starting point the number of input neurons was set to five and the number of hidden layers was set to four and trained for 5000 epochs. An epoch is one cycle through the series: present a subset of the training set, measure the error and update the weights in the network. The number of previous points fed back into the network ranged from one to three. Above three, the size of the FFNN becomes large. The best predictions were obtained with four and eight hidden neurons. There is no significant advantage in the network learning for more than 2000 epochs, as the RMS prediction error did not improve significantly. With eight hidden neurons, learning levelled off at around 2600 epochs. With four hidden neurons, the training sequence had only 2000 epochs.

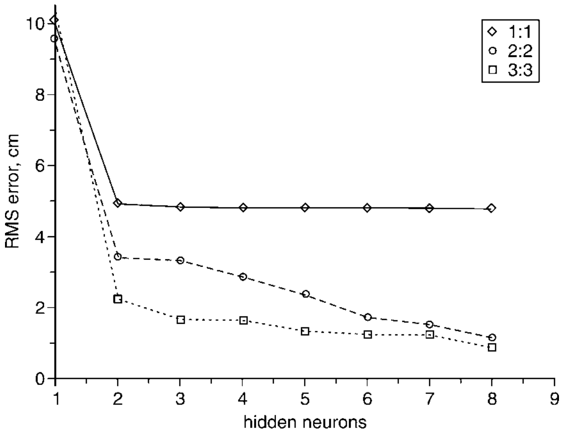

Fig. 2 *x-axis RMS error*

As an example, the RMS prediction of the y-axis plotted against the number of hidden neurons is shown in Fig. 2. The three lines represent the number of previous points fed into the network. Using more than two hidden neurons significantly reduces the error of the prediction, and using more than eight results in an RMS prediction of less than 1.0 cm; well within the size of the kaleidoscope locations. Best predictions of future positions were obtained with four and eight hidden neurons. An

RMS error of 1.6 cm is tolerable and with four hidden neurons that allows only two previous steps to be used; the middle line in Fig. 2. Fig. 3 shows some typical test data. The error in the x-axis prediction of the position of the photodiode is shown when the photodiode is moving across a screen in a random sequence. The RMS error of the x-axis is 2.42 cm. A summarised comparison of the results from 20 tests on three types of movement is provided in Table 1.

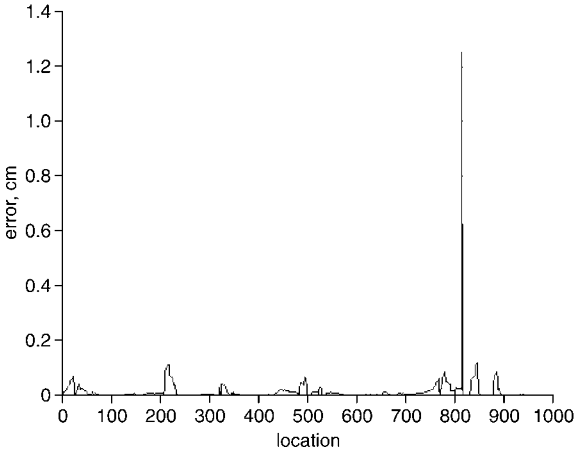

Fig. 3 *x-axis random movements prediction error*

Table 1: Summary of x- and y-axis prediction error

Line style	x-axis RMS prediction error (cm)	y-axis RMS prediction error (cm)
Signatures	2.54	0.45
Random	1.5	2.42
Diagonal	0.35	0.42
Collective	1.46	1.1

Conclusions: A new method that uses a kaleidoscope of colours flashed onto a computer screen is presented. Photodiode sensors are compact but may not always be accurate enough to detect sufficient colours on a full screen for use in this application. An ANN system allows the kaleidoscope to become dynamic since it can change its size and colour to increase the accuracy of the system. The output from the new system successfully differentiated colours on a TFT screen and converted them into co-ordinates that were then used to move a cursor. The low-cost method is interchangable between CRT and TFT screens and is currently being considered for applications in harsh environments such as seagoing and workshop computer systems. Research is continuing to include optics to focus the sensor.

15 April 2005

Electronics Letters online no: 20051388
doi: 10.1049/el:20051388

D.A. Sanders, G.E. Tewkesbury and B. Gremont (*Systems Engineering Research Group, Anglesea Building, University of Portsmouth, Anglesea Road, Portsmouth PO1 3DJ, United Kingdom*)

E-mail: david.sanders@port.ac.uk

S.D. Urwin-Wright (*MotionTouch Ltd, Unit 9, Dunsfold Business Park, Cranleigh, United Kingdom*)

References

1 Buck, G., and Hunka, S.: 'Development of the IBM 1500 computer-assisted instructional system', *IEEE Ann. Hist. Comput.*, 1995, pp. 19–31
2 Urwin-Wright, S.D., Sanders, D.A., and Tewkesbury, G.E.: 'Computer screen pointer using intelligent colour sensing systems', *Sens. Rev.*, April 2005, ISSN: 0260–2288
3 www.mazet.de/mazet_e1/opto_e/int_e.html on 14 October 2004
4 Cheng, H.D., Jiang, X.H., Sun, Y., Wang, J.L.: Color Image Segmentation, Advances & Prospects. Utah State University. Taken from www.cs.usu.edu/~cheng/paper.ps on 14 July, 2004
5 Urwin-Wright, S., Sanders, D., and Chen, S.: 'Terrain prediction for an eight legged robot', *J. Robot. Syst.*, 2002, **19**, (2), pp. 91–98
6 Han, C.W.: 'Genetic design of logic-based fuzzy controller', *Electron. Lett.*, 2004, **40**, (5), pp. 293–294