Advanced Escape Route System using Bistable E-Paper Displays and Dynamic Rerouting

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Escape route signs help people find their way in an emergency. Today, these signs are static and direct always in the same direction. We designed and prototyped a dynamic escape route system with bistable e-paper displays, fire detectors, cameras and a system controller. Various displays from E Ink were evaluated successfully and optically measured regarding reflectance and color.

1 Introduction and motivation

Fire alarms are situations with high stress. Therefore, a proper escape route strategy is demanded. However, today's escape route signs [1] and plans are static. We experienced that in a hotel with two identical staircases (Fig. 1). Which one do you select under stress? The next one might not be the best one e.g. if the fire there on the ground floor or there is a congestion. Such a situation applies also for fire escape plans which are often confusing and offer several escape routes. So we designed a smart escape route system using sensors, cameras with artificial intelligence (AI)-based detection of people (Fig. 2, standing, running, lying, jams …). Bistable displays are essential in case of power down as they maintain the "last" information.

Fig. 1 *Experience in a hotel which triggered our project: Fire alarm at 5 a.m. in Queen's Hotel, Dundee, UK with two identical staircases: Which one to choose? The nearest one or the one without fire, smoke, congestion …?*

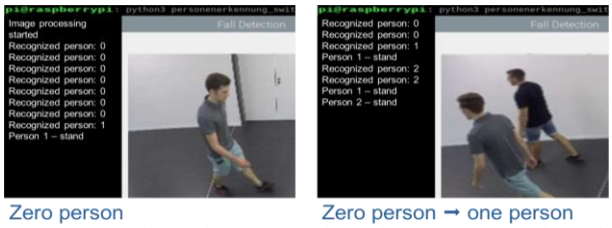

Fig. 2 *Our approach using artificial intelligence to detect and group persons with Tensor Flow [2] on Raspberry Pi.*

2 Demonstrator

We designed and prototyped a demonstrator (Fig. 3, Raspberry Pi 4 as main controller incl. AI analysis and dynamic rerouting) with pushbuttons to simulate fire(s), a dynamic sign (wireless, 4 directions: left, right, up, down) at a staircase, one camera (live) or video replay for demonstration.

Fig. 4 shows the software flowchart (left) to calculate the optimum escape route for each sign and an example of the visualization for path calculation.

An example of a spreading fire with dynamic rerouting (□) of escape signs (and optimized ways, possible jams detected by camera) is shown in Fig. 5.

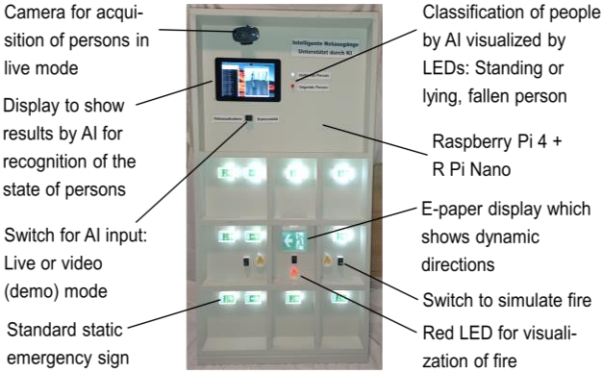

Fig. 3 *Photo of our demonstrator of a smart dynamic escape route system using sensors, an AI camera (here for demo) and an e-paper display.*

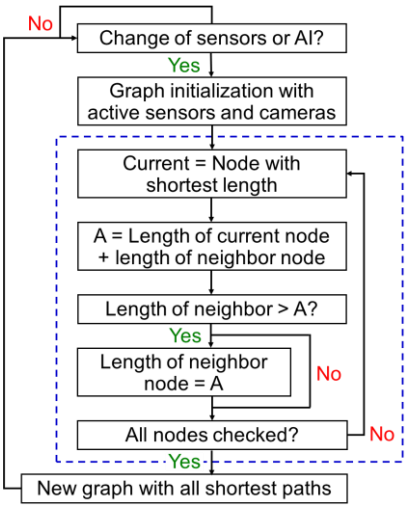

Fig. 4 *Simplified block diagram of our algorithms for optimal path per sign which is updated in real time.*

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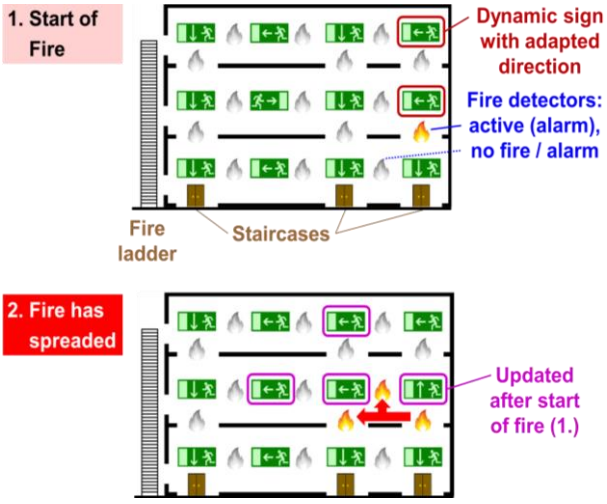

Fig. 5 *Example for dynamic escape route optimization (□) after start of the fire (top, one "flame") and sometime later the fire has spreaded (bottom, three "flames").*

3 Optical and photometrical measurements

An essential parameter of escape route signs is readability. We performed measurements (details see [3]) regarding the essential characteristics for our e-paper displays from E Ink: monochrome (2 particles) and ACeP (4 colored particles). A static German DIN escape route sign was tested as well.

The change of direction should be realized in short time. Fig. 6 shows the image update refresh of two E Ink panels: The monochrome display (top) shows an acceptable performance (evaluated by some subjects) as "blinking" (inversion of content e.g. white to black to white background) forces attention. 35 sec. for the color display (bottom) with four color particles is definitively too long. So, we propose a two particle system with white and green (like monochrome) for bistable dynamic escape route signs.

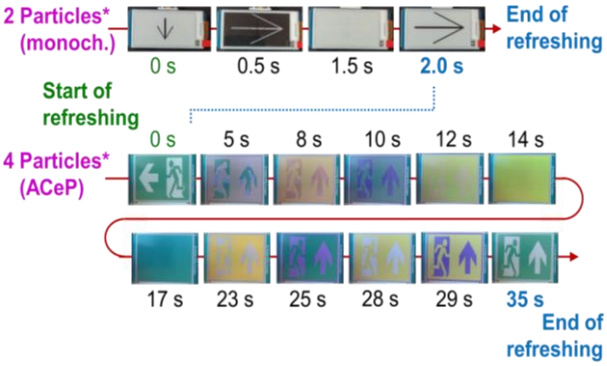

Fig. 6 *Image updates of monochrome (top) and color (bottom) E Ink displays (* number of different image forming micro-capsules by E Ink).*

As it might be relative dark in buildings due to emergency lighting, the reflectance of this light by the display should be high to ensure attention. The contrast ratio is a measure of fore- to background and represents readability. The reflectance and contrast ratio of e-paper is about half of a standard escape route signs (Tab. 1). The dedicated green particle of ACeP is close to the DIN color (Fig. 7) while the gamut of a monochrome e-paper using color filter array (CFA) is too small to notice colors in darker environments (refresh time like monochrome).

Diffuse illumination in dark room conditions	Reflectance	Contrast Ratio	
		White	Black
E Ink Kaleido, RGBW CFA, 2 particles	43 %	4.7 %	9 : 1
E Ink ACeP Gallery, 4 particles	37 %	4.2 %	9 : 1
DIN Signal white / black; RAL 9003/4	85 %	5.5 %	15 : 1

Tab. 1 *Reflectance and contrast ratio of our DUTs.*

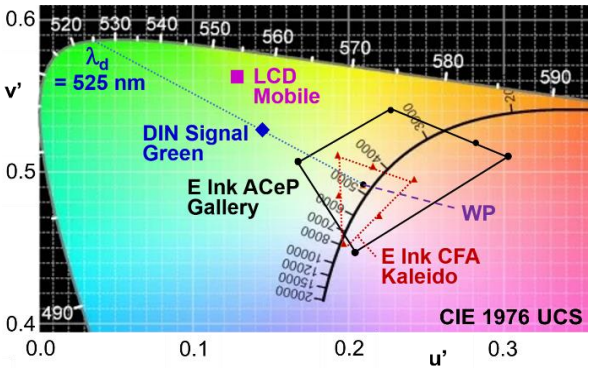

Fig. 7 *CIE 1976 UCS color coordinates for e-paper (black and red lines and dots), standard DIN signal green (dominant wavelength of 525 nm) and "green" of a commercial mobile phone LCD. WP: White point.*

4 Summary

Today's static escape route sign are not optimal. Therefore, we designed and engineered a prototype and demonstrator system using bistable e-paper displays for dynamic escape route optimization:

- The rerouting is calculated by a dedicated algorithm with sensor inputs and AI-assisted camera input for detection of fires, congestions, fallen people, blocked routes etc.
- Our optical measurements of bistable displays from E Ink proved readability and color. The best escape route display would be a customized E Ink film using white and green particles.

References

[1] ISO 7010:2019: "Graphical symbols Safety colours and safety signs"

[2] A. Gulli, A. Kapoor, S. Pal, *Deep Learning with TensorFlow 2 and Keras*, (Packt Publishing, Birmingham, 2019)

[3] K. Blankenbach, "Optical Measurements for E-Paper Displays, in *E-Paper Displays*, B.-R. Yang (ed.) (John Wiley & Sons, 2022), pp. 271-285