Ubiquitous Service Discovery using TRIP

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ABSTRACT

We are investigating printed symbols as a tangible representation of Web services, to allow mobile users to identify and interact with local services available in (foreign) pervasive environments. We have extended the TRIP symbol recognition algorithm to allow larger address spaces for this purpose, and have implemented a prototype on a desktop computer. We present the results of testing recognition performance using 51 bits per symbol, varying the symbol size, orientation and distance from the camera. We show that these extended TRIP symbols are a feasible tangible representation for Web services in ubiquitous environments.

Keywords

Ubiquitous (Web) services, computer vision

INTRODUCTION

The increasing number of users able to access Web services while on the move is leading to the introduction of new services aimed at mobile users. An instructive scenario might involve a user at a bus stop using a mobile phone to find out the arrival time of the next bus.

Links to such services must be represented in the physical world in a way that allows both users to discover the services that are relevant to their current location, and for services to discover the current location of the user. This is currently achieved by displaying prominently a Uniform Resource Locator (URL) which must be typed into a handheld computer to access the service. However, URLs are inconvenient to type on a small keypad, so it is desirable to find an alternative representation.

A number of previous research projects have addressed this issue. The Cooltown project at HP [3] represents services by infra-red beacons and radio frequency identifier (RFID) tags, though in practice this would be more expensive than printing URLs. Furthermore, RFID tags are likely to be less socially acceptable since, for example, a tag embedded in a business card in somebody's pocket may be read by other people in the vicinity. The ETHOC system [5] uses printed barcodes to represent services, but barcodes are hard to spot and impossible to decode at a distance.

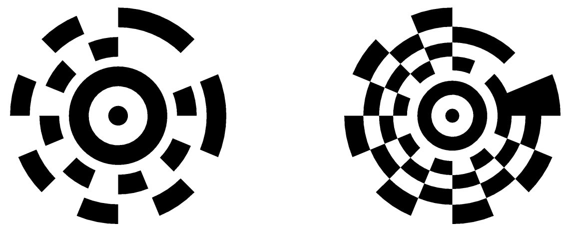

Figure 1: TRIP symbols

In contrast, Robinson and Hild [4] propose that, since many mobile phones are now equipped with inbuilt digital cameras, printed symbols could represent services in such a way that the user accesses a service by taking a photograph of the symbol, using software on the phone to decode the symbol in the resulting image. Symbols would be cheap to produce and socially acceptable, and large symbols printed on posters could be decoded at a distance, while small symbols could be printed on business cards and tickets.

We implement a prototype of such a system on a desktop computer, extending the Target Recognition using Image Processing (TRIP) symbol recognition system developed by López de Ipiña [1][2]. We test the prototype and discuss the experimental results obtained through initial deployment.

SYSTEM DESIGN

The use of a mobile phone presents several constraints: it has limited computing power; and the inbuilt cameras are typically of low resolution, with fixed focus, and adapt poorly to different illumination conditions. Furthermore, the decoding process requires reliability and timeliness, taking no more than a few seconds for a "point and shoot" application.

The TRIP system presented by López de Ipiña exhibits good performance with low-resolution cameras in sub-optimal lighting conditions. It provides an address space of around 21 bits per symbol, using two data rings each with 13 data sectors as shown in Figure 1. TRIP both decodes the symbol and estimates the location of the symbol relative to the camera, though the latter feature is not addressed in our work.

We extended the TRIP algorithm by generalising it to allow arbitrary numbers of data rings and sectors, and hence arbitrarily-sized address spaces. Each ring can be individually positioned and sized, and two sectors in each ring are used as a checksum.

EXPERIENCES

The extended recognition algorithm was implemented on a desktop computer and applied to images captured using a SonyEricsson P800 phone.

The symbol scheme we tested uses four data rings, each with 13 data sectors, as shown in Figure 1, to provide an address space of around 51 bits per symbol. This could, for example, encode a 32 bit IP address and a 19 bit identifier, or simply encode a number which is translated to a URL via a central database. The size and positions of rings are based on the results of preliminary tests: white space between the data rings was removed; extra space was created between the bulls-eye and innermost data ring; and the two outermost rings are slightly thicker.

We tested different sized symbols at various distances from the camera. The orientation (angle in the horizontal plane between the plane of the symbol and the line from the camera to the centre of the symbol) was also varied. All images were captured in well-lit indoor conditions, ensuring that the symbol was not in shadow. Figure 2 shows test results for symbols whose physical diameters were between 2cm and 16.5cm, at angles of 90º, 60º and 45º. *Pixel width* is the greatest horizontal distance across the area occupied by the symbol in the image, measured in pixels.

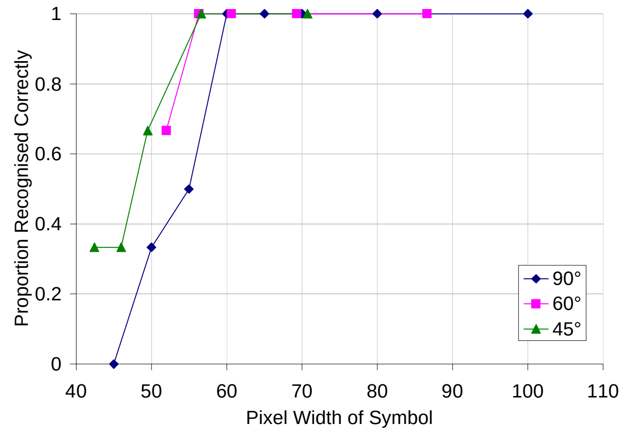

Figure 2: Recognition Performance

The graph shows that symbols from this scheme which occupy an area in the image of at least 60x60 pixels are almost always decoded correctly. At 90º this corresponds to the camera positioned around 30cm from a symbol with 2cm diameter, or 220cm from a symbol with 16.5cm diameter. Symbols whose physical diameters were less than 2cm were never decoded because they were either out of focus or occupied too small an area in the image. Images were captured in a lossy-compressed format, so these results are a conservative estimate of the recognition performance of an application using uncompressed images directly from the camera. In all cases symbols were either decoded correctly or not decoded at all, indicating that the algorithm is reliable.

The implementation processes a frame in around 60ms when running in Java on a desktop computer with a 1.4GHz processor. We have not yet estimated the time required when running on a mobile platform.

CONCLUSIONS

We have implemented and tested an extended version of the TRIP recognition algorithm, and experimental results indicate that a symbol scheme which provides around 51 bits per symbol is suitable as a tangible representation for mobile Web services. Symbol recognition is reliable, and recognition performance is good both for small symbols (e.g. 2cm in diameter) that could be printed on tickets or business cards, and for large symbols (e.g. 16cm in diameter) that could be printed on posters and decoded at a distance.

Comprehensive testing is required to determine an optimal symbol scheme and the timing performance on a mobile platform. Further work will address the practical issues associated with the deployment and use of such a system, and situations in which users find it beneficial.

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