Digital Hopscotch: Exploring the Relationship between Positioning Accuracy and Location Size *

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Introduction and Definitions

Location based applications for mobile computing have become of increasing interest to the research community, and are entering daily usage by the general public. Examples of this range from GPS based navigation systems for vehicles and pedestrians to 'where's my nearest' applications for mobile phones. Emerging applications include gaming and location based entertainment. In this proposal we intend to explore the relationship between the position sensing system and the location or target to be recognised. As part of this research we are seeking a method for the objective evaluation of such systems.

The words 'position' and 'location' are commonly used as synonyms – a dictionary definition of position is a strategic point, and of location is a particular place. These, and other dictionary definitions, do not help us clearly define the use of these words in a ubiquitous computing context. Thus for the purposes of this paper we define a position as a point in space with specified 3D co-ordinates and a known error distribution; and a location as a defined place or area with an assigned label. This is in accord with Hightower and Borriello's definition of 'physical position' and 'symbolic location' [1]. Examples of position are thus 51deg 32.789min N, 2deg 15.357min W, altitude 102m, with a standard deviation of 15m; or x=15.45m, y=6.28m, z=-7.14m relative to a known fixed origin with a 30cm standard deviation. We use standard deviation as this does not assume a particular error distribution. In this paper we assume a normal distribution, however this may not be the case and the effect of other distributions could well be a subject for further research. Examples of location are Bristol (within the City Boundary), or MacDonalds (inside the restaurant).

The performance of a location-based application often depends on the accuracy of the position sensing system. A GPS based city navigation system that correctly identifies which part of a street the user is on is considered acceptable, however a similar navigation system based on mobile phone cell recognition would be of little use.

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In this paper we propose to use an ultrasonic postioning system to facilitate a simple game of hopscotch with a PDA interface. By varying both the positioning accuracy and the target location size we propose to collect suitable data to enable us to establish a relationship between accuracy, location size and application effectiveness.

Fitts' Law

The objective of this proposal can be compared to Fitts' Law [2]. The time taken to acquire a target on a destop computer screen is predicted by this law, which states the time is a function of the distance to, and size of, the target. Mathematically this can be expressed as:

$$T = klog_2(D/S + 0.5)$$

where k = 100 msec, T = time to move the hand to a target, D = distance between hand and target, and S = size of target.

Fitts Law is a powerful tool for predicting the performance of a *pointing* based application, usually involving a mouse and screen interface. Many variations have been derived including those by Meyer [3] and MacKenzie [4] who recognised the original law's one dimensional constraint.

The objective of Fitts Law is analogous in the real world to the physical acquisition of a target location by a moving subject. However additional factors need to be considered. The speed with which a mouse pointer traverses a display screen is assumed not to have a first order effect while the speed of a moving subject is patently relevant to the time needed to move to a location in the real world. The accuracy of the positioning of a mouse pointer can also be determined to the nearest pixel, whereas in the real world we are subject to the vagaries of physical position measurement.

We thus hypothesise that for an ubiquitous location based application, the time taken to acquire a target location will depend on the distance to the target, the size of the target location, the speed of the user, and the accuracy of the position measurement system. While this may seem intuitive, our objective is to move towards providing application designers with a usable formula in the same way that Fitts' Law supports desktop application design.

Position Sensing

There are many position sensing technologies available for research purposes [1]. For our experiments we require a system which will provide coverage over a limited area with an accuracy predicted to be greater than that needed for the chosen application. GPS accuracy, while suitable for navigation at street level, has proved problematic at smaller scales [5]. The accuracies provided by systems integrating ultrasonics or magnetic sensing with inertial techniques [6, 7] far exceed our anticipated needs, and do not provide coverage over a large enough area.

For our requirements we propose to use ultrasonic positioning with a reference RF signal as pioneered by A.T.&T. [8]. The Bristol Ultrasonic Positioning System [9] provides an accuracy of better than 20cm over an area of 8m x 16m. This system relies on a synchronising RF pulse followed by a number of timed ultrasonic chirps transmitted from known positions in the infrastructure. A receiver decodes these signals and provides a position to a wearable or handheld computer.

Game Proposal

The elements which we require for our game include a measured position, a target location, a distance to be traversed, and performance of a player measured in time. For the results to be meaningful it is necessary for some form of unpredictability to be incorporated to prevent the player second guessing the system.

The game of 'hopscotch' meets these requirements, however we wish to create uniform, but still unpredictable, paths for the players to follow. A pattern of eight squares, whose size can be varied for each game, can be used to provide eight equally long paths which can be chosen at random (see Figure 1).

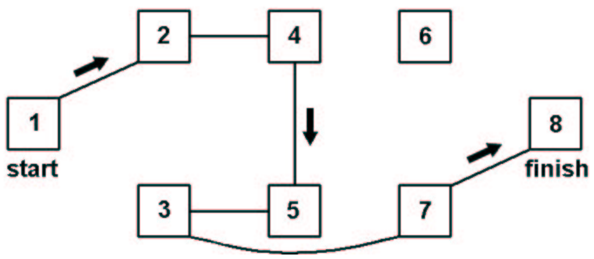

Figure 1: Layout and typical path.

The player is guided along the chosen path by a PDA application. Success at reaching each square is measured using the positioning system with a pre-determined noise factor introduced to preset the accuracy of the position sensing. By timing each player from start to finish and combining this with the varying location size and positioning accuracy data we expect to be able to establish a potential relationship between the three variables.

Conclusion

In this paper we have presented a practical approach to reasoning about the relation between sensed position and targeted location size. This will yield results to assist designers of location based applications. While much work has already been undertaken examining similar issues for desktop computing, little has been done to objectively assess the relative performance of positioning systems for location based applications. We believe that this games based solution has the potential to contribute to this line of research.

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