Ranking Significant Ubiquitous Computing Trails

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Trails as primitives for Navigation

Similar to physical and information spaces, *trails* are also a useful mechanism to provide navigational assistance in ubiquitous computing environments. For example, trails can represent context histories. moreover, they provide an effective way to record, structure and represent interactions between users and physical or digital resources within a single framework.

To make this approach practical several challenges must be met since trail-based navigation requires considerable storage and computational resources when carried out naively. We propose new methods and techniques that can effectively address these performance considerations and can support processing of large numbers of recorded trails implemented within our *navigation engine*.

System Architecture

The navigation engine consists of:

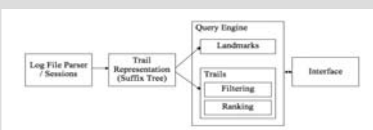
•a sessioning tool for reading data collected from the ubiquitous computing environment

•a probabilistic tree data structure which represents the recorded trails

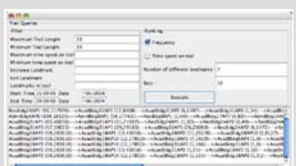
•a framework for the definition of metrics used to calculate the best route under different circumstances during navigation, and

•mechanisms that can calculate such routes efficiently from the tree data structure.

•These routes can then be used by the user as an indication of how to navigate in the ubiquitous computing space.

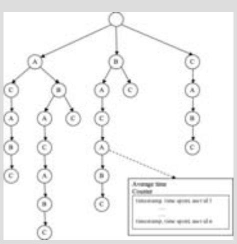


System process and architecture



Query interface

Trail Representation



All interactions are captured and represented as a node within a network representation in the form of a probabilistic grammar. Sequences of interactions recorded for a specific user specifically within a particular session are called trails and are represented as directed paths across the network graph.

We have extended the *suffix tree* data structure to develop a data primitive suitable for this task which we call the *interaction tree*. This tree structure and associated algorithms represent and efficiently query the interaction network. The interaction tree provides an effective mechanism to identify so-called significant trails that is trails that best match specific measures of prominence.

Trail Ranking

Significant trails are discovered via a pruning of the interaction tree T. The *pruned tree* is defined to be a sub-tree of T which contains a selection of trails that meet specific criteria. For example, trails that are the most commonly followed between two particular landmarks or else the tree probability defined below

$$P(\mathcal{S}) = \sum_{i=1}^{m} P(T_i),$$

is greater than a required probability mass.

More on Significance Metrics

In addition to frequency, it is possible to define several additional significance metrics (depending on the data available) for example time, orientation, identity, semantics or other meta-data. A time related metric we often used is define for each trail T as follows

$$N(T) = \frac{Time(T)}{Sum(Times(LeafNodes))},$$

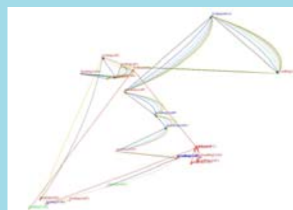
It is also possible to use metrics that are weighted combinations of the above metrics i.e. weight the significance of frequency and time.

The effectiveness of each possible metric is still an open issue.

Case Studies

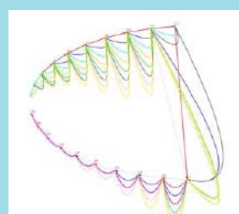
Testing with three data sets

- Dartmouth-Crawdad wireless campus data
- Intel-Cambridge imote experiments
- Location traces with visitors at the London Zoo

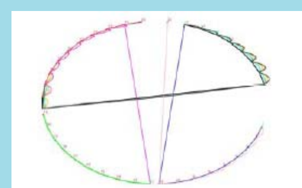


Time. Best trails in the Dartmouth wireless network data: top 5 trails in terms of time and of length 10 with at least 7 distinct landmarks visited

Frequency. Best trails in the Dartmouth wireless network data: top 5 trails in terms of frequency and of length 10 with at least 7 distinct landmarks visited



Composite. Best trails in the imote wireless network data: top 5 trails in terms of weighted frequency and time



Frequency. Best trails in the imote wireless network data: top 5 trails in terms of frequency and of length 10 with at least 7 distinct landmarks visited

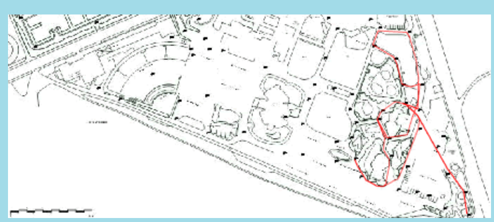


Exhibit Trails. Best trails at the London Zoo. Visitors are tracked using GPS. Landmark positions have been selected to correspond to specific exhibits and also using Space Syntax (path visibility nodes)

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