

# Route Generation for Adaptable Trails-Based Applications

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Adaptive trails-based applications are a class of mobile applications that assist users in task planning, management and navigation. The trails metaphor is a useful abstraction that allows us to research problems common to a wide range of mobile applications operating in a ubiquitous computing environment. For the high level concept of a trail to be successfully implemented in the real world there must be a way to perform real time dynamic route generation on resource limited mobile devices in a cooperative and transparent manner. Current route generation takes little advantage of contextual information and is usually concerned with optimising a route in relation to a single cost function. We are investigating the generation of routes that can incorporate a much richer understanding of context beyond simple location sensing and temporal awareness. This paper discusses how current route generation techniques may be improved on, using collaboration, machine learning, mobile agents or genetic algorithms.

## 1 Introduction

The term ubiquitous computing refers to the idea of invisible computers. In such an environment many low interaction, non-intrusive devices both on your person and in the environment communicate and exchange information (context) to assist you accomplish your daily tasks while minimising distractions.

Context has been described as any information that characterises the situation of any entity relevant to the interaction between a user and an application [2]. In our case context-awareness refers to the ability a mobile application has to adapt its interface and functionality based on the context information that is available to it. Contextual information is already available to today's generation of mobile devices. Through the advances in network positioning and geo-location, devices are increasingly spatially and temporally aware. The future will see many more sources of context becoming available.

We are investigating applications that assist users in navigation from one place to another. We refer to this class of applications as trails based.

A trail [1] is a high level abstraction and consists of a collection of locations with contextual information and a prioritised order for visiting them. Trails underpin a wide range of useful applications and make it possible to explore adaptive characteristics common to all mobile, context-aware applications.

- Trails are personalised to specific users.
- Trails are dynamic in that they must remain appropriate even if information about a task or other contextual information changes.
- Trails will have to be generated on resource limited mobile devices.

Applications based on the concept of a trail have inspired the development of a middleware-based framework for context-awareness in mobile applications which we call *Hermes* [3]. The goal of *Hermes* is to provide to future ubiquitous computing technologies, the means to enhance and augment

human perceptual capabilities with automatically sensed and disseminated context that influences route generation. Changing routes trigger a reconfiguration of the device interface, providing the user with the ability to make better decisions based on context awareness beyond simple location sensing.

In order to develop the framework, a small number of applications are in development. The first of these is the *Oisín* application, which provides support for users to plan appropriate routes around campus in order to achieve a pre-determined set of tasks.

The remainder of this paper will present the route generation algorithm currently in use by *Oisín* and will explore a number of possible alternatives commenting on the advantages, disadvantages and research challenges associated with each.

## 2 Route Generation in *Oisín*

A core component of a trail is the routes between its activity locations. *Oisín's* route generation component currently uses the Floyd-Warshall all-pairs shortest-paths algorithm to calculate the shortest path between two locations. This algorithm has an exponential running time which is overcome by pre-computing an adjacency matrix at compile time. This allows route generation to happen very quickly but it also means that the weights on the edges of the graph are fixed. The fixed weights prohibit the adaptation of routes to a dynamic environment in real-time without losing the optimisation of the pre computed matrix.

## 3 Route Generation Alternatives

Traditional approaches to route planning have focused on ways of generating optimal routes where the only cost factor was distance. Possibly the most famous optimal route algorithm is Dijkstra's algorithm. A\* is a heuristic searching algorithm which is used quite extensively in route planning applications and improves on Dijkstra's algorithm by taking weighting (cost) factors in the environment into account.

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Both these shortest path approaches are exponential in nature and can only make use of limited static context. In order to raise the value of generated trails we require the route generation to incorporate many more sources of dynamic context beyond simple location sensing.

One approach to this problem is to apply techniques from the field of artificial intelligence and machine learning. Case Based Reasoning (CBR) has been applied to generate experience based routes, where experience is the collection of past routes taken. Current research uses simple feature based extraction of routes for case retrieval [4]. This approach does not take the best advantage of the context information to optimise the retrieval set. Current research also does not address real-world issues such as the physical size of a case base.

Current CBR approaches fail when presented with a problem in which they have little experience. This is often referred to as the pump priming problem and recent advances in inductive learning and relevance feedback may provide a solution to this problem. Current systems will often fall back to shortest path algorithms resulting in poor quality routes. This solution is inadequate as it is when the user is in an environment in which they have no experience that more assistance is required.

The potential for the use of collaborative context acquisition provides us with the possibility of applying a collaborative filtering approach. This technique has been successfully applied to problems in other domains. A good example of collaborative filtering is Amazon.com's recommendations system, which bases recommendations on experience with groups of 'similar' users. Measuring similarity between users in order to share experience is likely to be the major research challenge in this approach. The issue of reliably propagating route experience across distributed mobile devices in an ad-hoc networking environment would also have to be solved.

A possible extension to CBR based routing would be to partition the case base into localised areas of experience. A software agent could passively gather experience of a specific physical area by observing transiting mobile devices, becoming essentially an expert on navigation in its locality. This entity could then provide its knowledge base as a statically located service to location aware mobile devices who can query this knowledge base for routes. This approach addresses the case retrieval bottleneck but assumes the availability of fixed nodes in the environment, which may not always be the case.

Genetic Algorithms (GA) have also been proposed for use in route planning [5]. GA's are adaptive search algorithms for searching for near optimal solutions. They work by generating a representation of a route that is evolved through each iteration of the algorithm. After each round of evolving the possible routes, an evaluation function checks to see which new routes are moving toward a solution and evolves only those routes in the next iteration. This approach has been applied in the military domain for aircraft route planning [6]. Research in this area has produced solutions that do not evolve in response to the

environment. Route planning for aviation is also a simpler problem than route planning in a ubiquitous computing urban environment where there are many more restrictions on the choice of possible route.

Research in synchronous groupware and distributed virtual environments suggests a possible collaborative approach to building augmented digital maps where context information is disseminated in order to provide a coherent model of a space to route generators. Traditional route generation algorithms could be augmented with a semantic context ontology language, facilitating adaptation through use of a rule base, weighing of routes based on ontological context reasoning or by narrowing or pruning the search space of possible routes based on a level of environmental awareness.

In order to generate trails that are personalised and adaptable, route generation must be efficient. The combination of traditional heuristic route planning, combined with a collaborative approach to case based reasoning and finally learning from when a user deviates from a route will be a comprehensive approach to the problem.

#### 4 Future Work

In order to further develop context-aware route generation algorithms we intend building additional context-aware trails based mobile applications and conducting user trials. User trials are believed to be the most accurate way of measuring the success of context-aware route generation since route quality is subjective and may be influenced by collaborative context over which we may not have full control. User trials will also allow us to investigate to what level users are prepared to trust the route generation process to a ubiquitous computing system.

#### 5 References

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