Universal Navigation through Social Networking

Mahsa Ghafourian[1], Hassan A. Karimi[1], and Linda van Roosmalen[2]

[1] Geoinformatics Laboratory, School of Information Sciences, University of Pittsburgh, 135 North, Bellefield Ave, Pittsburgh, PA 15213 USA
Mag158@pitt.edu, hkarimi@mail.sis.pitt.edu
[2] Department of Rehabilitation Science and Technology, 2310 Jane St Suite 1300, University of Pittsburgh, Pittsburgh, PA 15203 USA
Lvanroos@pitt.edu

Abstract. In today's complex metropolitan and aging society, navigation, which is an essential mobility activity, has become increasingly challenging for many individuals. This is particularly true for individuals who are unfamiliar with the area or require special navigation assistance due to visual, physical, or cognitive impairments. While there have been much advancements in navigation systems, they are one-size-fits-all and not universal. In this paper, we present the concept of Universal NAVIgation Technology (UNAVIT), which is a framework providing navigation assistance anywhere, anytime, and for any user through social networking (UNAVIT-SN). We discuss UNAVIT-SN, its components and features, and present key algorithms for providing suitable navigation solutions both indoors and outdoors, at different times and for users with a variety of needs and preferences.

Keywords: Universal navigation, social networking, social matching, route recommender, navigation assistance.

1 Introduction

Navigation systems assist users with determining their current location and providing directions to desired destinations. While early navigation systems were one-size-fits-all and offered limited functionality, today's navigation technology offers a wider range of functions that appeal to more users resulting in a higher demand for its use. However, despite much advancement, today's navigation technology falls short of being universal. By universal we mean a navigation system which provides navigation assistance to users with different needs and with different preferences, anywhere and anytime [1].

To overcome the shortcomings of modern navigation technology, in this paper, we present Universal NAVIgation Technology (UNAVIT) and discuss a new approach in addressing the universality of navigation in UNAVIT [1]. We define navigation as any activity requiring locations and the means to reach them. Examples of navigation that fit this definition include points of interest (POIs), routes, and directions. To address universality of navigation, Ghafourian and Karimi [2] have developed three algorithms, ANYWHERE (indoor-to-outdoor and outdoor-to-indoor seamless transitions), ANYTIME (time-specific navigation), and ANYUSER (personalized navigation). The

A.A. Ozok and P. Zaphiris (Eds.): Online Communities, LNCS 5621, pp. 13–22, 2009.

work presented in this paper is focused on a novel approach which provides navigation assistance through "social connection" and "social matching" using social networks. This is in contrast to the current navigation approach which is purely computational. The premise of the social networking approach in navigation stems from two observations: (a) social networking has become widespread, enabling the possibility of tackling some of the navigation challenges that computation alone could not and (b) developing a computing solution that can address all aspects of universal navigation is a major undertaking and may not even fully be realized due to several technical and non-technical challenges. We believe the social networking approach is viable in that UNAVIT-SN will be able to address the issue of universality through existing and emerging social networks, especially when the element of "trust" is considered and computing is only used when no navigation solutions can be provided by social networks or the solutions need to be augmented.

In this paper, we present a technique that searches for navigation information through UNAVIT-SN, which consists of several social sub-networks (SSNs) each supporting a group of individuals with common navigation needs. The structure of this paper is as follows. In Sections 2, social networking and its relevance to navigation are discussed. In Section 3, the concept of UNAVIT-SN, an ontology, and an infrastructure are discussed. In Section 4, our social networking approach to address the requirements of universal navigation is described. Finally, in Section 5, we discuss our future research.

2 Background

A social network is a structure that consists of a group of people in which each member is represented by a node and one or more relationships exist among members [5]. The emergence of mobile technologies has changed the ways in which people communicate with one another [6] and share information in such a way that separation of space and time is virtually nonexistent. Research in social psychology shows that people construct a shared reality within social networks, and not only share the information, but also have agreement on them [13].

In a study conducted by Gray et al. [4] it was shown that social participation by individuals with mobility limitations is affected by environmental barriers. Some of these barriers are the inaccessibility and complexity of the man-made environment with busy roads, dangerous intersections, dark alleyways, inaccessible buildings, among others. Other barriers include the inability of people to navigate due to physical, cognitive and sensory limitations, impeding their participation in society.

Among numerous existing social networks, each with a different purpose and interest, we focus here on those social networks that are relevant to navigation. Millen and Feinberg [7] have developed a "social tagging" method, using bookmarking, which provides navigation recommendation. MobSoC [8] is an approach which offers a variety of services to users including POIs recommendation based on users' interest. Wiggle Stick [9] is a technique which enables pedestrians with "media tagging" at specific locations as well as presenting directions.

In order to meet the quality of services within a social network, the exchanged information among the members must be based upon "trust", i.e., receiving recommendations and information from trusted friends who have similar preferences. This trust-based approach helps users receive effective and relevant information. To address trust in quality of services and quality navigation recommendations, a variety of techniques have been proposed, such as collaborative filtering [10], a technique for measuring social tie strength offered by [11], and a fuzzy model used by [12].

3 UNAVIT-SN

To overcome the shortcomings of existing navigation technology, we propose UNAVIT-SN. UNAVIT is defined as a navigation environment capable of providing a variety of navigation information for any user regardless of their location in any situation with the capability of transparency and adaptability [1]. While a social networking approach can address the universality aspect of navigation, computation can still play a role. It can be used as augmentation and/or verification. By augmentation we mean the possibility of sending a navigation solution found and offered by UNAVIT-SN to navigation web services to assist the user with real-time navigation (e.g., step-by-step instructions on the recommended route). Verification aims at providing a reliable solution, i.e., if the navigation solution offered by UNAVIT-SN is deemed unreliable, then a solution from navigation web services will be requested, and after comparing the two solutions, the one which closely matches user's requested Navigation Quality of Service (NavQoS) is chosen as the response to the query. However, the focus of this paper is navigation assistance through social networks.

Figure 1 shows the overall concept of UNAVIT-SN, whose main features include AnyUser, AnyWhere, AnyTime, Transparency, and Adaptability [2] through social networking. Users will be able to access UNAVIT-SN's services using cell phones.

A user can either recommend or request navigation information. Recommendations are posted in the user's SSNs. Upon user's request for navigation information, UNAVIT-SN searches within the user's SSNs, and if it cannot find a match, it refers it to other SSNs.

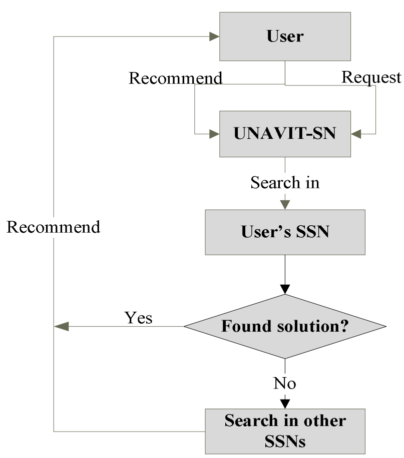

Fig. 1. The concept of UNAVIT-SN

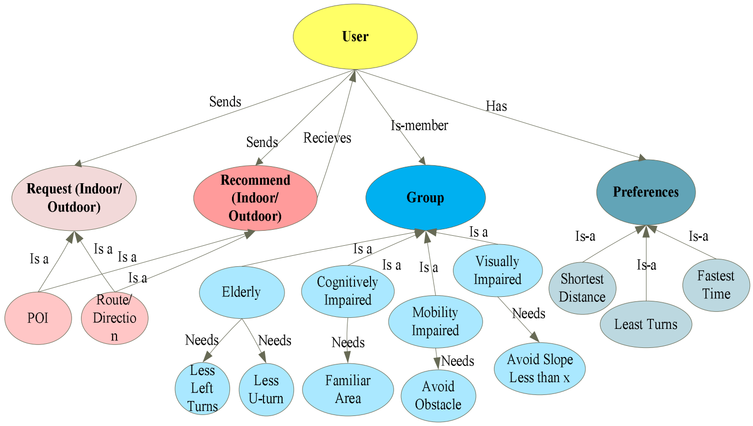

Fig. 2. UNAVIT ontology

3.1 Ontology

We address the universality aspect of navigation by taking a social networking approach. We believe this approach is viable since social networks have been widely accepted and utilized by people across the globe. Therefore, UNAVIT-SN's infrastructure should allow navigation information through SSNs, where individuals have similar navigation needs.

Figure 2 shows an ontology for UNAVIT-SN. It highlights the main concepts of universal navigation through social networking and the relationships among them.

In this ontology, user plays a central role by sharing their profiles to other members of the SN. User's profile consists of special needs (elderly, cognitively impaired, mobility impaired, and visually impaired) and preferences for routes (shortest distance, fastest time, least turns).

The user can recommend navigation information and can receive navigation recommendations from other members. A request can be made for a route or for a POI. A recommendation can also be on a route or a POI.

3.2 Infrastructure

In this section, we discuss UNAVIT-SN that is based on UNAVIT's infrastructure [2]. In the following, the architecture of UNAVIT-SN and its components are discussed.

NavKiosk: NavKiosk is the major component of UNAVIT-SN's infrastructure and is responsible for receiving navigation queries from users. NavKiosk for indoors (Indoor-NavKiosks) is responsible for indoor navigation queries and NavKiosk for outdoors (Outdoor-NavKiosks) is responsible for outdoor navigation queries. NavKiosk consists of three sub-components: QPE, MetaNav, and NavNet which are described below.

Query Processing Engine (QPE): QPE is responsible for analyzing and understanding queries using NavQoSs. Upon analyzing a query and understanding its requirements, QPE will structure the query in a manner compatible with MetaNav, NavNet, and NavWSP.

MetaNav: MetaNav is a directory of information about UNAVIT-SN and its members, and all other NavKiosks (both indoors and outdoors). Examples of items stored in MetaNav are SSN types, social ties and characteristics within and among SSN members and among SSNs, and the geographic extent covered by each NavKiosk.

Navigation Networking (NavNet): UNAVIT-SN will allow users to establish their own social networks as well as accessing existing social networks for the purpose of sharing navigation information. Through NavNet, UNAVIT-SN will facilitate sharing the experience of trusted members and groups with similar needs and preferences. NavNet uses information about trusted members and social networks stored in MetaNav to connect members and groups who have sharable navigation experiences.

Navigation Web Service Provider (NavWSP): NavWSPs provide a variety of navigation services, including map data, POIs, and directions, as an augmentation and/or verification to social networking solutions. It uses the Internet and can be accessible directly through cell phones. An example of a NavWSP is Routing NavWSP.

4 Social Matching

In order to share navigation experiences among individuals and groups through UNAVIT-SN we make distinctions between five social sub-networks (SSNs): General (G); Mobility-Impaired (M); Cognitively Impaired (C); Elderly (E); Visually Impaired (V). Each of these SSNs provides navigation information specific to their members' special needs. For instance, a recommended route in M is a route that a wheelchair-seated individual can take as it avoids slopes over a certain degree and avoids inaccessible POIs.

Each SSN is connected to one another (i.e., fully connected graph). The graph is weighted and directed. Each node of the graph represents a SSN as a sub-graph, which is also fully connected. The idea behind having a fully connected graph is that once a user becomes a member of a SSN, they can share and access navigation experiences of all members in that SSN. In the following we discuss users' interactions within SSN, i.e., recommendations and requests.

4.1 POI and Route Recommendation

Each member of a SSN can recommend navigation information. While a variety of information is possible, most recommendations are expected to be POIs and/or routes. Upon recommending a POI, the type of POI and the value of recommendation are specified by the user (recommender). We categorized POIs into five types: Restaurant/Fast Food, Gas-Station, Library/Bookstore, Shopping Mall, and Grocery Store. Each recommendation is assigned a value which represents the importance (strength) of the recommendation. We define three recommendation strengths: Low, Medium, or High. For recommendations on a route, we define three criteria for each route: Shortest Distance (SD), Fastest Time (FT), and Least Turns (LT). If the user does not specify the criterion for the recommended route, the information from user profiles will be used. A route recommended by a user may indicate a level of importance (weight) on each criterion. The weight for each criterion may range between 0 and 1 and the sum of the weights for the three criteria must be 1. Each recommendation must also have a quality rate, i.e., Low, Medium, or High denoted by 11, 12, and 13, respectively. The algorithm for recommendation is shown in Figure 3.

```
Input: user recommendation

If recommendation = "POI" then
        T ← Get type of POI;
        R ← Get recommendation rate;
If recommendation = "route" then
        SD ← Get shortest distance value;
        FT ← Get fastest time value;
        LT ← Get least turns value;
        R ← Get recommendation rate;
If SD = null or FT = null or LT= null
        SD ← SD from user's profile;
        FT ← FT from user's profile;
        Lt ← LT from user's profile;
```

Fig. 3. Recommendation Algorithm

4.2 Navigation Information Request

Users acquire navigation information by sending request to UNAVIT-SN. It is assumed that users prefer to receive information from trusted members within their SSNs. Therefore, UNAVIT-SN first tries to find a match between users' request and a trusted member's recommendation. We define "trust" as the number of referrals/interactions between each pair of members. This referral has a direction, as user A might refer to user B many times, but user B may refer to user C rather than user A for navigation information. Thus, in each SSN, the direction of information between each set of nodes (members) denotes the orientation of the referral by one member to another. NR_{ij} indicates the number of referrals by individual i to individual j. Initially, $NR_{ij} = NR_{ji} = 1$. Over time NR will increase as more referrals are made.

UNAVIT-SN must find a trusted member within the SSN whose recommendation meets user's requested NavQoSs. The probability of referral of i to j, P_{ij} is defined as follows:

$$P_{ij} = \frac{NR_{ij}}{NR_{ij} + NR_{ji}} \tag{1}$$

Also, $P_{ij} + P_{ji} = 1$. Thus, in the initial stage when there are no referrals in the SN, $NR_{ij} = NR_{ij} = 1$ and $P_{ij} = P_{ji} = 0.5$.

Input: User "A", User's NavQoS, User's SSN ("S")

1) For each recommendation within the "S" in UNAVIT-SN
   Find solutions which are recommended by trusted friends, and which matches NavQoSs.
2) For each found solution recommended by member i
   Exclude the ones with $P_{Ai} = 0.5$ and $NR_{Ai} = 1$.
3) Among remaining solution, choose the one with the highest value of SM and insert its value into variable SM_M.
4) If no solution is left then
   $SM_M \leftarrow 0$
5) If SM_M is less than a predefined threshold, then
   Result ← Referring_SSN(NavQoS, "S");
   If Result = "No Result" then
   Return the solution to the user with low confidence.
6) Otherwise,
   Increment $NR_{Ai;}$
   $P_{Ai} = \frac{NR_{Ai}}{NR_{Ai}+NR_{iA}}$;

   $P_{iA} \leftarrow \frac{NR_{iA}}{NR_{Ai}+NR_{iA}}$ $P_{iA} = \frac{NR_{iA}}{NR_{Ai}+NR_{iA}}$;

Fig. 4. Request Algorithm

The difference between the values of P_{ij} and P_{ji} indicates how much i and j trust one another. The less the difference, the more the trust (thus more chances of referrals), unless NR=1, which means that these members have never referred to each other. Once user i refers to user j, the value of NRij increments by one.

The same concept can be applied to the relationship between SSNs. That is, SSN-A is connected to SSN-B through a weight, NR. Initially, NRs value is 1. However, the value of NR will increase as more referrals between SSNs are made.

The idea behind having connections between SSNs is that if UNAVIT-SN cannot find a navigation solution or a reliable solution for a request within a SSN, it refers to another SSN to find a reliable solution. Figure 4 shows an algorithm for request. The inputs to the algorithm are user's query, NavQoSs, and the SSN to which the user belongs.

For a recommendation to socially match the user's request, the value of SM in the algorithm must be greater than or equal a threshold.

Figure 5 shows an algorithm (Referring_SSN) which is invoked when there is a need to search of navigation solution in another SSN. In this algorithm, upon a successful referral, NRs between SSNs are updated. The inputs to this algorithm are NavQoSs and the relevant SSN, i.e., "S".

Input: user's NavQoS, User's SSN ("S")
1) For each SSN, i, with $P_{Si} \geq 0.5$ do
Find recommended solutions by majority of members, which match NavQoSs;
2) For each found solution recommended by SSN "i"
Exclude the ones with $P_{Si} = 0.5$ and $NR_{Si} = 1$;
3) For the remaining solutions
Choose the one with the highest value of SM and insert it into SM_M;
4) If $SM_M < \delta$ then
Return "No Result";
5) Else
Increment NR_{Si};
$P_{Si} = \frac{NR_{Si}}{NR_{Si}+NR_{iS}}$;

$P_{iS} = \frac{NR_{iS}}{NR_{Si}+NR_{iS}}$;

Fig. 5. Referring_ SSN Algorithm

In order to compute "social matching", we divide navigation requests into two groups: POIs and Routes.

POI

There are three variables that define a POI: Type, Recommendation, and Distance. Type consists of five categories: Food, Gas-station, Library/Bookstore, Shopping Mall, and Grocery Store. Each Type category can be initialized by either "match" or "exact match". For each Recommendation, three values are defined: Low, Medium, and High. Finally, for Distance, which is the distance between user's current/specified location and a POI, the value can be either entered by user or suggested by the system.

Consider user A's request for an Italian restaurant, which is in the category of Restaurant/Fast Food within 10 miles. User A must indicate whether he/she is interested in an "exact match", i.e., an Italian restaurant, or a "match", i.e., any restaurant but preference will be Italian restaurants. Also user A must specify the degree of recommendation by members, i.e., whether the rate of the recommendation is "High", "Medium", or "Low". If user A chooses "exact match" with "Medium" recommendation, QPE analyzes the query and sends it to NavNet to find an Italian restaurant recommended (with "Medium" rate) by trusted members of user's SSN. To select those restaurants within 10 miles, user's current location is used by a NavWSP to perform proximity calculation based on actual road distances.

For "social matching", NavQoS is defined as follows:

$$\text{NavQoS} = T * R \,. \tag{2}$$

where T and R represent the distinct values for Type and Recommendation, respectively.

The set of values {1,2,3,4,5} corresponds to POI types, i.e., {Restaurant/Fast Food, Gas-Station, Library/Bookstore, Shopping Mall, Grocery Store}, and {11,12,13} correspond to POI recommendation rate, i.e., {Low, Medium, High}.

And "social matching" is defined as follows:

$$SM = \frac{P_{iA}}{(T_i - T_A) * (R_i - R_A)} . \tag{3}$$

where i corresponds to a member of SSN whose recommendation is considered and A corresponds to the requester.

The more the value of P_{iA} (i.e., close to 0.5) and the less the value of $(T_i - T_A) * (R_i - R_A)$ (i.e., close to zero), the higher the social match, i.e., the recommended POI socially matches user's request.

Route Recommendation Options

We consider three criteria for routes, Shortest Distance (SD), Fastest Time (FT), and Least Turns (LT), as the most preferred criteria, among others. Each criterion can be assigned a value between 0 and 1. However, the sum of the values must be equal to 1. Members who recommend routes are encouraged to initialize the recommended route's criterion and the level of each recommendation, R, i.e., Low, medium, or High. If users do not enter route criteria, those specified in their profiles will be used.

There could be two cases when user A requests a route from Origin (O) to Destination (D), with for example SD = 0.5, FT= 0.3, LT=0.2. In the first case, UNAVIT-SN searches user's SSN for a route from O to D with criteria equal or close to values 0.5, 0.2, and 0.2, respectively. In the second case, UNAVIT-SN is not able to find a route from O to D, but it finds one or more routes that overlap candidate routes between O and D and have equal or close criteria values. If these routes pass through O-D, the one with closest "social match" is returned to the user.

In both cases, either finding a path from O to D or a path that passes through O and D, NavQoS is defined as follows:

$$\text{NavQoS} = \text{ST} * \text{FT} * \text{LT} * \text{R} . \tag{4}$$

where again the set of {11, 12, 13} corresponds to the values for R, i.e., {Low, Medium, High}.

In order to select an appropriate recommendation among the available ones, social matching score, which is defined as follows, must be greater than or equal a threshold.

$$SM = \frac{P_{Ai}}{(ST_i - ST_A) * (FT_i - FT_A) * (LT_i - LT_A) * (R_i - R_A)} . \tag{5}$$

where i corresponds to the recommendation from member I, A corresponds to the requester, and P_{Ai} is the value of trust between A and i.

The more the value of P_{Ai} (i.e., close to 0.5), and the lower the value of $(ST_i - ST_A) * (FT_i - FT_A) * (LT_i - LT_A) * (R_i - R_A)$ (i.e., close to zero), the higher the social matching score, i.e., the more the recommended route socially matches user's request.

5 Summary and Future Research

In this paper we presented the concept of UNAVIT-SN as a universal navigation technology through social networking which provides navigation solutions to any user, anywhere, and at anytime, transparently and adaptively. We then discussed a social networking approach that allows users request navigation information and receive navigation recommendations from members of their social networks. We presented the algorithms for navigation recommendation and navigation request which meet NavQoSs.

Future research includes development and validation of a prototype UNAVIT-SN with selected SSNs (e.g., general, elderly, mobility impaired, visually impaired, cognitively impaired) to facilitate navigation recommendation and request through cell phones.

References

1. Karimi, A.H., Ghafourian, M.: Universal Navigation. GIM International (May 2009)
2. Ghafourian, M.: Karimi, H.A.: Universal Navigation Concept and Algorithms. In: World Congress on Computer Science and Information Engineering (CSIE). IEEE Press, LosAngeles/Anahiem (2009) (accepted)
3. Golbeck, J.: Sharing and Using Links in Social Networks. IEEE Intelligent System, 85–86 (2005)
4. Gray, D.B., Hollingsworth, H.H., Susan, S., Kerri, M.A.: A subjective measure of environmental facilitators and barriers to participation for people with mobility limitations. Disability and Rehabilitation, 1–10 (2007)
5. Jamali, M., Abolhassani, H.: Different Aspects of Social Network Analysis. In: Proceedings of the 2006 IEEWICIACM International Conference (2006)
6. LaRue, E.M., Mitchell, A.M., Karimi, H.A., Kasemsuppakorn, P., Roongpiboonsopit, D.: COMPANION: Social Support Networking Technology For Survivors of Suicide. In: International Conference on Health Informatics (HEALTHINF 2009), Porto, Portugal (2009)
7. Millen, D.R., Feinberg, J.: Using Social Tagging to Improve Social Navigation. In: Workshop on the Social Navigation and Community-Based Adaptation Technologies Conjunction with Adaptive Hypermedia and Adaptive Web-Based Systems (AH 2006), Dublin, Ireland (2006)
8. Borcea, C., Gupta, A., Kalra, A.: The MobiSoC Middleware for Mobile Social Computing: Challenges, Design, and Early Experiences. In: Mobilware 2008, pp. 1–6 (2008)
9. Jimison, D., Sambasivan, N., Pahwa, S.: Wiggle Stick: An Urban Pedestrian Mobile Social Navigation System. In: Georgia Tech Graduate Symposium, Georgia Tech, Atlanta (2007)
10. Jung, J.J., Kim, K., Lee, H., Park, S.: Are You Satisfied with Your Recommendation Service? Discovering Social Networks for Personalized Mobile Services. In: Nguyen, N.T., Jo, G.S., Howlett, R.J., Jain, L.C. (eds.) KES-AMSTA 2008. LNCS (LNAI), vol. 4953, pp. 567–573. Springer, Heidelberg (2008)
11. Adams, B., Phung, D., Venkatesh, S.: Extraction of Social Context and Application to Personal Multimedia Exploration. In: MM 2006, Santa Barbara, California, pp. 3–4 (2006)
12. Korfiatis, N., Sicilia, M.A.: Social Measurement and Flexible Navigation online Contact Networks. In: Fuzzy Systems Conference (2007)
13. Nowak, A., Vallacher, R.R.: Information and Influence in the Construction of Shared Reality. IEEE Intelligent System, 90–93 (2005)