

# Towards Meeting Assistance: An Integrated Appointment Assistance and Group Pedestrian Navigation System

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**Abstract.** People often go out with other people, meet friends and prefer covering distances together. 70% of all pedestrians travel in a group according to Moussaïd et al. However, most pedestrian navigation systems are intended for single users only. For closing this gap we built a meeting assistance system for groups of users who want to meet. This paper will present the challenges of building such a system, just as solutions for making appointments, calculating appropriate meeting points and routes using Steiner Trees.

**Keywords:** appointment assistance, group pedestrian navigation system, Steiner Tree problem.

## 1 Introduction

People go out together. This was ascertained by Moussaïd et al. who says that 70% of all pedestrians travel in a group. [1] The sizes of pedestrian groups were measured by [2]: 71.07% were groups consisting of two individuals and 28.93% were groups consisting of two to seven individuals. The average group size is 2.41 individuals. However, most pedestrian navigation systems are intended for single users only. For closing this gap we built a mobile Integrated Appointment Assistance and Group Pedestrian Navigation System for users who want to meet. With the help of this system, users can get assistance in making appointments and finding appropriate meeting points and routes to their common destination.

Imagine two first-year fellow students living in two different student dormitories spread across a city. They agree to go to the cinema. On their way they want to talk to each other about their current lectures. But they also have to finish their homework first so they do not want to have too much detour. Thus a compromise between detour and the time walking together is needed. Where should they meet?

This paper we will present our approach to help people solve this everyday problem. First, we will present the state of the art of pedestrian navigation systems and group recommendation systems in Section 2. This Section will also discuss group sizes of pedestrians for motivating the need for multi user and

group pedestrian navigation systems. The integrated appointment assistance and group pedestrian navigation system is presented in section 3. The next Section 4 focuses on the appointment assistance part. We introduce and evaluate different flows of user to user interaction and present our implementations. The group navigation system and a brief overview of the underlying theoretical problem for calculating the meeting points and routes is presented in Section 5. We conclude and give an outlook for further research and development in section 6.

## 2 State of the Art

### 2.1 Pedestrian Navigation Systems

To aid people reaching their destination, current pedestrian navigation systems give turn-by-turn instructions and show routes to the destination on detailed maps. Many commercial and freely available systems are in use. However, most to the authors known pedestrian navigation systems are for single users only. Examples of such systems are Google Maps Navigation, ovi maps, MobileNavigator, PECITAS [3], P-Tour [4], RouteCheckr [5], COMPASS [6] and many more. Besides that, most commonly used routing algorithms for street networks or public transport networks (like [7] and [8]) are single source only. They cannot be used to calculate routes for more individuals who want to meet.

There are some exceptions to these single user PNS. One is a prototypical system from [9] which helps people to meet. The system calculates an area which is reachable by all participants in time and calculates direct routes to a single meeting point in this area. There are also commercial systems which assist exactly two users in finding a meeting point. MeetMe (<http://aboutmeetme.com>) and MeetWays (<http://meetways.com>) recommend meeting points halfway between the two users. To this point they also find individual routes. This is done by first calculating the shortest path between the two users and second recommending places of interest (POI) which are near to the middle of the calculated path. These two commercial systems indicate, that there is a need for group navigation systems. For further supporting our claim for this need we will have a look at typical group sizes of pedestrians.

### 2.2 Group Sizes of Pedestrians

While there exist numerous studies about animal group sizes, only few exist for human group sizes. One of the first studies about human group sizes originates in the year 1951, when James measured group sizes in politics and in public places, e.g. pedestrians, in department stores, playgrounds. In [2], he determines a mean group size of 2.41 for people in informal groups. A total of 7405 groups have been studied. 71,07% of all groups consisted of two persons, the other 28,93% have been groups between three and seven persons. In this study, the counting of individuals has not been taken into account. The subsequent paper [10] declares a mean group size of 1,46, if individuals are considered. James also

deduced a generalized model of pedestrian group sizes from this data, but this model has been proven incorrect by [11]. From James' data we can calculate, that 34.46% of all groups (including groups of size 1, namely individuals) are groups of two or more people. To a different result comes [1], who observed, that up to 70% of pedestrians in a commercial street walk in groups. Note the difference between the latter two units of measurement. By converting James' result, we find that 55.14% of all pedestrians in James' study are walking in groups. Now one can easily see that the results of the two studies differ about 15%. Further and more detailed studies are needed. These results show that many people go out in groups and support our claim that there is a need for group navigation systems.

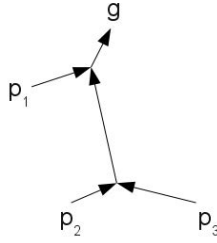
### 2.3 Appointment Assistance

Settling on destinations, good meeting points and routes can be seen as a task for group recommender systems. Jameson and Smyth [12] give an overview of such systems. They structure recommendation in a process of four recommendation subtasks: preference acquisition, generation of recommendations, presentation of recommendation and assistance in achieving consensus. The research on the last subtask "assistance in achieving consensus", which we will call negotiation subtask, is in most publications on group recommenders only rudimentary discussed, as [12] noted. Most systems only present recommended items to their users and leave the choice of a specific item to the users. Examples for such systems are PolyLens [13], Trip.Easy [14] and CATS [15]. In these systems the final choice is achieved by discussions of the users outside of the used system. Travel Decision Forum [16] is a group recommendation system which focuses on the negotiation. In this implementation this phase consists of a discussion which is supported by a visualisation of the user's arguments like people talking in a comic strip.

While group recommendation systems often leave out the negotiation subtask, there is a field of research which addresses the problems which arise here. Group (Decision) Support Systems (GDSS) assist groups in arriving at a final decision. (e.g. [17]). We think, that group recommender systems should also include such a GDSS. We think, that group recommendation is in fact a *process*, in which the subtasks of group recommendation are blend with the subtasks of GDSS. One can not just recommend an item to the group, the item must be narrowed down in a dialog among the group members and with the recommender.

### 2.4 Steiner Tree Problem

The Steiner Tree Problem will be used to calculate meeting points and corresponding routes. Hence we will give a short introduction to this problem, namely to "Find the shortest network spanning a set of given points. . ." [18]. A minimal tree for 4 terminals shows the graph in Figure 1.



**Fig. 1.** Meeting tree of three individuals  $p_1, p_2, p_3$  meeting at intermediate points on their way to their common destination

Two similar versions of the Steiner Tree Problem can be found in literature:

**Steiner (Tree) Problem in Networks (SPN).** Given an undirected network  $N = (V, E, c)$  with vertices  $V$ , edges  $E$  and cost function  $c : E \rightarrow \mathbb{R}^+$ , and a terminal set  $T \subseteq V$  find the subnetwork  $S$  of  $N$  such that all nodes  $t \in T$  are connected and that the total costs  $\sum_{x \in E_S} c(x)$  are a minimum.  $S$  is called Steiner Minimum Tree (SMT). SPN is NP-complete [19]. An overview of exact and approximative algorithms as well as a introduction to SPN is for example given by [18] and [20].

**Euclidian Steiner (Tree) Problem (ESP).** Given a set  $T$  of  $n$  points in the Euclidian plane, find a tree  $S$  connecting all  $t \in T$  minimizing the length of  $S$ . Note that this might introduce new points at which edges of the tree meet. A prominent exact algorithm was given by [21], heuristics e.g. by [22] and [23]. *Geosteiner* [24] implements an exact algorithm with special pruning techniques to rule out implausible SMTs. Detailed information can be found in [25].

### 3 Integrated Appointment Assistance and Group Pedestrian Navigation System

We have identified two main phases of going out. In a first phase, the appointment phase, the destination and the time to meet have to be agreed upon. In the following meeting phase individuals proceed to the common destination. There exist more phases, but we focus in this paper on the two presented. For appointment phase and meeting phase we built an assistance system each. The meeting assistance system (MAS) consists of two subsystems, the Appointment Assistance System (AAS) and the Group Pedestrian Navigation System (GPNS). AAS helps individuals in the appointment phase to find and agree on a destination. After having settled on a destination, the meeting phase begins: routes for all individuals are calculated by the GPNS. These routes are not only routes directly from each individual to the destination, but routes where individuals meet at intermediate points on their way to the destination. Both systems are presented in the subsequent sections.

Our implementation of the meeting assistance system is built upon the pedestrian navigation system ROSE [26] and is basically structured as follows. Every user is running a client software on her mobile phone. One user can invite other users to a location, e.g. to a certain cinema. After the users have accepted the invitation, their GPS positions are sent to the server. On the server, routes for all users are calculated with appropriate meeting points. The server is implemented in Java EE and communication is done over RESTful webservice using JSON. The server stores user profiles, friends lists and event lists in a database. Also the server offers services such as geocoding, route generation for pedestrians with support of public transport and recommendation of events. These routes are displayed on the users mobile phones and allow turn-by-turn navigation for each user. Due to the fast progress from cellular phones to current smartphones, two versions of the client have been implemented for different platforms. The first one is implemented in Java Mobile Edition and is targeted for older mobile phones. The second one is implemented as an HTML5 web application and can be run with newer browsers and is especially targeted for being run in smartphone browsers. A more detailed description of the workflow of the clients can be found in the subsequent sections.

Currently, AAS and GPNS are coupled loosely. After the destination is settled upon, the result is passed to GPNS as input. For more elaborate systems in the future, characteristics of the routes of the individuals should be considered also in the appointment phase.

## 4 Appointment Assistance System

The AAS assists groups of individuals settle on a common destination and time. As we cannot rely our design on experienced data we build a flexible system which allows several task flows to be implemented. We then compared task flows to find an appropriate task flow for our scenario.

### 4.1 Task Flows in Java ME Client

The task flow of the user to user interaction can be modeled in different ways. We implemented different task flows and evaluated them. By using this method, we examined which user to user interaction workflow is best. Several flows have been implemented in the Java Mobile Edition client.<sup>1</sup> The flows are:

**Group Rating (GR):** The organiser of the group compiles a list of events which he wants to propose. The list is rated by all participants. Afterwards, the system calculates (by an arbitrary algorithm) which suggestion matches the interests of the group best.

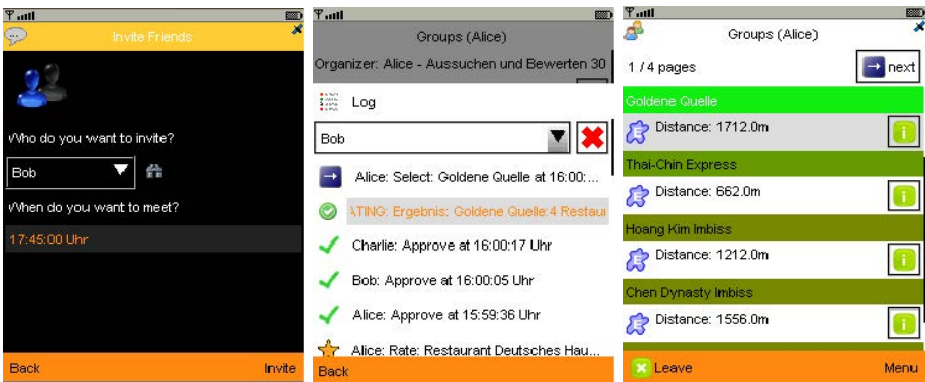
**Group Criticising (GC):** The organiser proposes an event. The participants can accept the proposal or suggest a different event. The process continues until all participants accept the proposal.

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<sup>1</sup> In all flows, various single user recommender systems can be used to compile lists of events. Using this technique, no group recommender system is needed.

- Group Rating after Criticising (GRC):** Like GR, but with a more elaborate process for the organiser to compile the list of proposed events.
- Individual Search, Merging and Rating (SMR):** Organiser and participants all propose one event and the proposed events are collected in a list. Now, everybody rates the events in this common list and the systems calculates (by an arbitrary algorithm) which suggestion matches the interests of the group best.
- Conjoint Criticising (CC):** A list of events is proposed by the organiser. By criticising events, everybody can change the list. Changes of the list are propagated to everybody. After some time, the organiser proposes an element from the list to the participants. If all approve, the process ends. Otherwise, the process of criticising is continued.

Screenshots of the Java Mobile Edition client displaying various dialogs of the appointment assistance can be seen in Figure 2.



**Fig. 2.** Screenshots of Java ME client: invitation, approval, list based selection

We conducted a study with nine participants to compare the presented flows against each other. Groups of participants had to employ each flow to settle on a destination. Criteria of the evaluation have been the duration of the flow  $t$ , average active time of all users  $\bar{t}_U$ , user satisfaction with outcome of the flow  $SO$ , user satisfaction with outcome of the process  $SP$  (both in relation to [27]) and a subjective voting “Which flow did you like best?” where  $v$  counts the votes the flow received. The results are presented in Table 1.

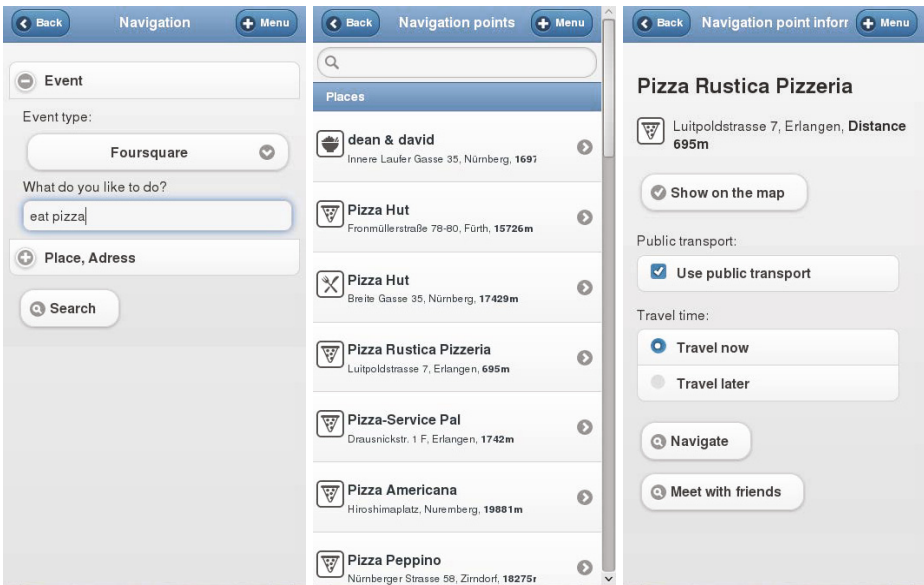
The fastest flow was GRC, taking 5:24 minutes and also the shortest average active time  $\bar{t}_U = 3 : 00$ . The flow SMR was rated the most satisfying by the organisers ( $SO_o$ ). Participants are most satisfied with the flow GC concerning the process ( $SP_p$ ) and GR concerning the outcome ( $SO_p$ ). Note, that participants are overall less satisfied with the flows than organisers are. The subjective vote shows, that most participants of the study prefer the SMR flow. This might be to the straightforward nature of the SMR flow.

**Table 1.** Overview of study results (best results are **highlighted**)

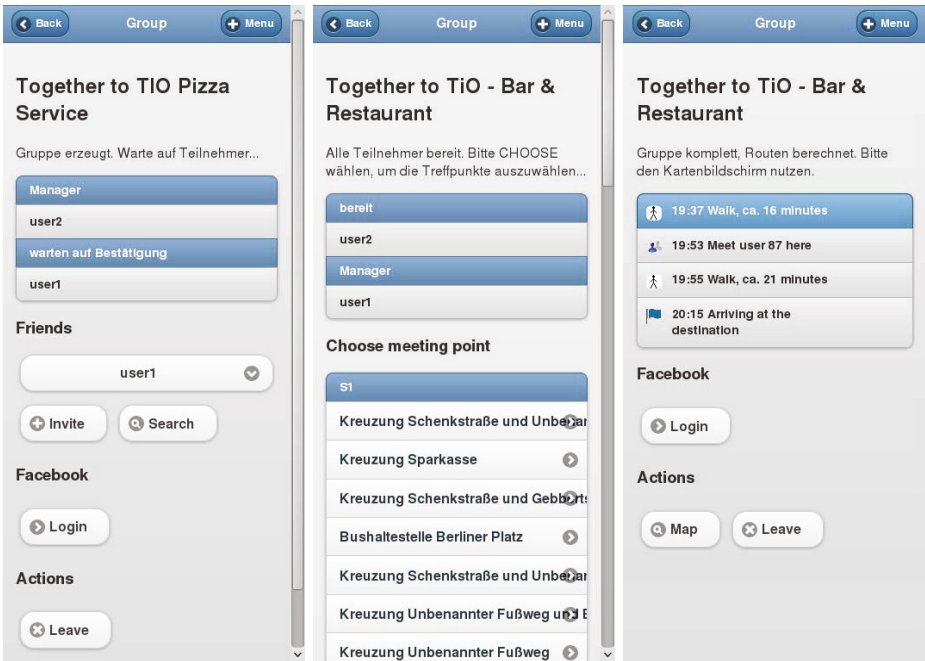
Flow	$t$	$\bar{t}_U$	$SO_o$	$SP_o$	$SO_p$	$SP_p$	$v$
GR	7:01	4:41	4.06	4.00	3.95	<b>4.35</b>	1
GC	6:25	3:08	4.25	4.63	<b>4.25</b>	4.10	2
GRC	<b>5:38</b>	<b>3:00</b>	4.19	4.69	4.05	4.20	0
SMR	9:53	8:17	<b>4.50</b>	<b>4.75</b>	3.55	3.95	<b>3</b>
CC	5:24	3:28	4.44	4.69	3.65	3.55	1

## 4.2 HTML5 Client

In the more up to date client based on HTML5 only one flow is available at the moment: the organiser of the meeting selects a destination and invites his friends. Destinations can be selected from the server’s or from Foursquare’s database. The Figures 3 through 4 show the flow described above for two users. At the beginning, a user, called the organiser, selects a destination (Figure 3). He then sends invitations to his friend(s) (Figure 3 *left*). After all friends have accepted or declined, meeting points and routes are calculated for all participants. If several good meeting points are available, the organiser can choose, which to take, e.g. to meet at a bus stop or in front of a bakery (Figure 3 *middle*). Finally, calculated individual routes are displayed for each participant (Figure 3 *right*). These routes show amongst others, where to meet the other participants. They can also be displayed on a map, as shown in Figure 5.



**Fig. 3.** Screenshots of GroupROSE (from left to right): search for places of interest (POI), overview of POI, POI details and possibility to invite friends



**Fig. 4.** Screenshots of GroupROSE (from left to right): Dialog to invite friends, select a POI as meeting point, overviews of route for user 1

## 5 Group Pedestrian Navigation System

After a settlement is achieved our system helps the individuals to navigate to the agreed destination. For this, the current positions of the participants and the destinations are passed to the GPNS. One can easily imagine, where the participants could meet: at the destination, at one of the participants homes or at some dedicated locations in between. Often, the latter is the case: People meet at intermediate locations to yield a good compromise between detour and conjoint travel. To the best of our knowledge there is no literature from other authors about meeting behaviour and especially meeting point finding of individuals. Thus we will give our own definition of the problem.

Given is a map of a city and a set of individuals starting positions and a goal position in that city. For each individual a route has to be found from it's starting positing to the goal position. All these routes together compose a meeting tree (MT). Now, find a MT such that a) the distances travelled together are maximized and b) the detour for doing so is minimized. These requirement correspond to the every day meeting behavior of people as observed by common sense. From a social psychological point of view we can formulate a different requirement: Find a MT such that the costs for all individuals are minimized. By assigning costs for detour and negative costs to distances travelled conjoint we transform



the common sense requirements to the social psychological requirements. These requirements also conform to rational choice theory (see e.g. [28]), which thinks of individuals as if they would choose actions to maximize personal advantage. We presented a more precise and formal definition of this problem in [29]. There we also show that the meeting problem can be reduced to a Steiner Tree Problem under the assumption that it does not matter whether we exchange starting positions and goal position.

Two general approaches can be used to solve the Steiner Tree Problem. At the beginning of our research we interpreted MTP as an instance of a SPN. Thus, we used an extended Dreyfus-Wagner algorithm as described in [20] to calculate the SMT in the network of the streets. Calculating a MT with three terminals on maps with a practical amount of streets took over 30 seconds (without precalculation step). As we wanted to construct a system with a response time smaller two seconds we explored a second method.

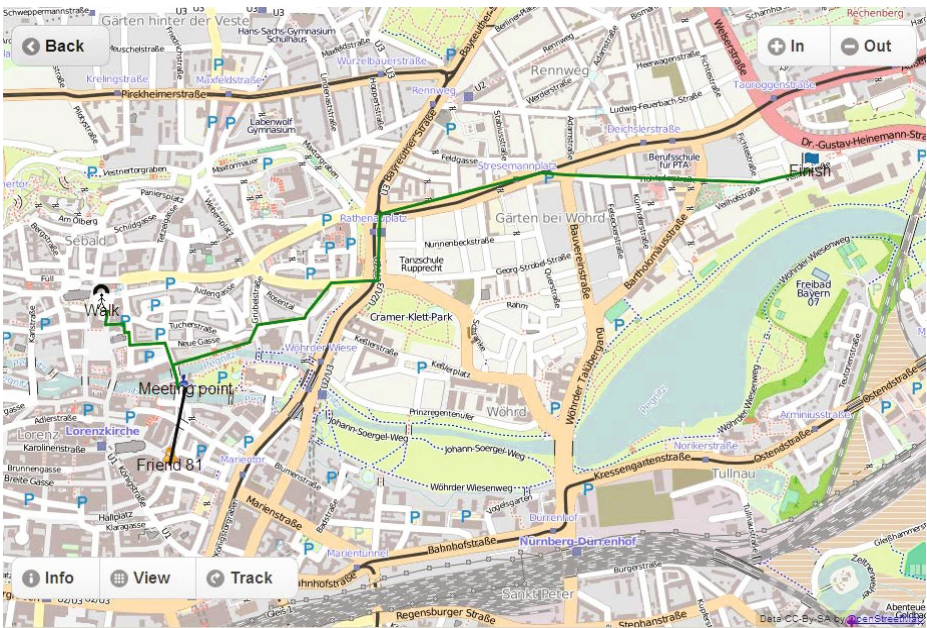


Fig. 5. GroupROSE Routes and meeting point for two people

“Pedestrian navigation [...] is not confined to a network of streets, but includes all passable areas, such as walkways, squares, and open areas, within or outside buildings.” [30]. Thus, pedestrian movement can be seen as largely independent of the street network. Inspired by their observation we neglect the actual structure of the street network in a first step. Now our problem resembles the ESP. Such, we can use e.g. the Melzak algorithm to estimate meeting points on a geometric basis only. For calculating meeting points in the ESP we relied on the

program GeoSteiner (see section 2.4). The runtime of GeoSteiner for our limited set of terminals is negligible short. We call meeting points obtained by solving an ESP theoretical meeting points (TMPs). TMPs calculated in the previous step can be situated in unaccessible places like buildings or lakes or unintuitive places. Thus, we move these points to better locations nearby, e.g. restaurants, bars, bus stops, subway stations, some points-of-interest (POIs), public open places or big crossroads. We used OpenStreetMap as source for finding MPOIs. Afterwards routes to these meeting points are calculated in the street network. This is done using OpenRouteService (<http://openrouteservice.org/>). Also times at which users have to be at specific locations are calculated.

Compared to the optimal solution this method results in an average of 12.5% overall detour [29], which is according to [31] acceptable for pedestrians. In [29] we discuss the calculation of meeting points and routes in more detail. Routes for all individuals can be displayed in the client. An example of a route for two users shows Figure 5.

## 6 Conclusion

People go out in groups. We built a meeting appointment system which consists of an AAS and GPNS to support people in making appointments, calculating routes to their common destination and navigating there conjoint. We proposed and evaluated several flows of user to user interaction. The flow “Individual Search, Merging and Rating” (SMR) was the best flow under investigation for supporting mobile users in making appointments according to the organiser’s satisfaction and the subjective votes. The fastest flow was “Group Rating after Criticising” (GRC). For calculating meeting points and routes we presented two methods which lead back to the Steiner Tree Problem. As the runtime of the method based on Steiner Problem in Networks is (at least when using the exact Dreyfus-Wagner algorithm) too high for our needs, we currently employ a method based on Euclidian Steiner Problem which neglects the street network.

In the future we want to add more flows to the HTML5 client and evaluate them. As meeting assistance systems is a new area of research there are still many open questions to answer and many aspects of meeting behaviour to be researched. At the moment, considering means of public transportation in multi user routing and group navigation is of particular interest to us.

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