Route2Health
A Novel Routing Service to Assist in Increasing Physical Activity

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Abstract: Walking is the simplest and most common mode of transportation and is widely recommended for a healthy lifestyle. However, other modes of transportation such as driving and riding are usually dominant when distances are too long to walk. Existing routing and direction services are designed to mainly serve common transportation requirements such as shortest distance, shortest travel time, minimum bus transfer, nearest bus stop, or closest parking lot. Existing services do not consider however, user's preference for walking as the primary option, especially when multi-modal transportation is involved. This paper presents the concept of a new service called Route2Health where walking, due to its several benefits including health, is considered as the preferred mode of transportation. Route2Health, as a multi-modal transportation planning service, recommends either walking, if feasible, between pairs of origin and destination locations as the only mode of transportation or a combination of walking with other modes of transportation. Route2Health, if used frequently, is potential to help increase physical activity levels overtime. A prototype Route2Health is also discussed.

1 INTRODUCTION

Walking is an essential mode of transportation, independent of vehicles or parking locations, and does not rely on specific service routes or schedules. Roads in urban and residential areas usually include sidewalks to connect building entrances and other locations that can be reached on foot. Walking plays an important role in multi-modal transportation planning. For example, when a person drives from home (origin) to another location (destination), walking maybe required between the parking lot and the location of destination. In the case of public transit, walking from an origin to a particular transit stop, from a transit stop to the destination, and between transit stops is commonplace.

Besides serving as a transportation mode, walking can offer interesting and desired benefits to travellers. For example, walking is considered as a physical activity that can generally be performed by many people regardless of geographic locations. It is recommended by the United States Department of Health and Human Services (1996) that moderate intense activities such as 30 minutes of brisk walking can lead to health benefits in adults. Numerous studies (e.g., see Besser et al. 2005; Sallis et al. 2004; Edwards 2008; and MacDonald et al. 2010) suggest that walking should be promoted as part of daily public transportation to prevent or mitigate various health conditions such as heart disease and obesity. Morabia et al. (2010) conducted a study and found that switching from private car to public transportation when commuting to work increased energy expenditure (more than 124 kilocalories/day) which is equivalent to the loss of 1 pound of body fat per 6 weeks. In an analysis of cross-sectional health and travel data at country, state, and city levels, Pucher et al. (2010) found negative relationships between active travel (waking and cycling) and self-reported obesity and negative relationships between active travels and diabetes. As a national agenda, walking is also promoted in Healthy People 2020[1] project which sets a goal to increase walking by at least 10%.

There is considerable variability in walking. For example, some people usually choose to walk up to a certain threshold, beyond which they will turn to other means of transportation. The threshold varies

[1] http://www.healthypeople.gov/2020/

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according to individual characteristics, for example, weight, gender, behavior, health, and age. Younger people with good health may be able to walk farther. Older people may prefer shorter distances, lower uphill slope, and better sidewalk surface conditions than younger people. For instance a negative relationship between age and speed of walking is reported by Himann et al. (1988). People who have an active lifestyle tend to walk faster, longer and more frequent compared to those who are less active. For example, a study by Bassett et al. (2008) shows that in Europe, North America, and Australia obesity rates have negative correlation with percentage of trips taken by active transportations (walking, bicycling, and public transit). Traveller's behavior also plays an important role, for example, health conscious and active people may accept longer and more intense walking paths than others. Given that walking is a common mode of transportation, highly susceptible to individual differences, and beneficial for good health, a new service that searches all feasible routes between a given pair of origin-destination locations and recommends one that includes walking is highly desirable. Finding walking paths that are optimal by taking into account multiple criteria through such a service is challenging. Current routing services, such as Google Maps, only consider common transportation criteria, for example, shortest travel time, shortest travel distance, fewest bus transfers, or minimum walking. Furthermore, none of the existing services takes into account individual health conditions.

The paper contributes by presenting a novel routing service, called Routh2Health, that recommends walking session(s), if feasible, for any trip. By taking origin, destination, and traveller's individual conditions as inputs, Route2Health recommends a sequence of transportation modes along with specific details about each mode that is most optimal (personalized). The rest of the paper is structured as follows. Section 2 discusses related work. Section 3 describes background information. Section 4 describes Route2Health in detail. Section 5 describes Route2Health prototype, and summary and future research are given in Section 6.

2 RELATED WORK

Multi-criteria routing research is focused on finding optimal transportation paths by considering multiple criteria (objectives) simultaneously. Bit et al. (1992) combined fuzzy set theory and linear multi-criteria programming to address a multi-objective transportation problem. Their fuzzy programming approach has been claimed to be able to address problems with large number of objectives and to be applicable to both minimum and maximum optimization problems. Modesti et al. (1998) proposed a utility measure that takes into account the overall travel expense, travel time, and bus crowded with passengers on public transport during rush hour. The utility values from the measure are then used as costs to find the optimum path using Dijkstra's algorithm. Das et al. (1999) proposed a solution to multi-objective transportation problems by expressing objective functions as interval degradation allowance values and then applying a fuzzy programming technique. Li et al. (2000) introduced a multi-objective linear programming model for transit itinerary planning and used it in a two-phase heuristic algorithm. The first phase generates all feasible paths with the objective of minimizing total travel time. The second phase is to evaluate the feasible paths by taking into account such decision criteria as number of transfer points, bus headway or frequency, and total travel expense, among other criteria.

Multi-modal public transport planning is another related area. Karimi et al. (2004) developed an Internet-based application for bus route planning with a minimum number of bus-to-bus transfers. Rehrl et al. (2007) designed a mobile application that provides personalized multi-modal trip planning, navigation assistance for transferring between buildings, and pedestrian routes in outdoors. Li et al. (2010) introduced a multi-modal trip planning system that incorporated real-time transit data into park-and-ride recommendations. Their system uses a prediction model (based on the regression analysis and historical data) to estimate the real-time transit arrival time. Tsolkas et al. (2012) described an architecture for a personalized mobile application and a multi-modal dynamic routing algorithm which takes into account real-time traffic information and individual routing preferences.

The work which is closely related to Route2Health was conducted by Sharker et al. (2012). The study discusses a new weight for segments of a pedestrian network to compute health-optimal routes. The weight, which is pre-computed and assigned to each segment, is calculated by taking into account physical space factors (such as segment length and safety), environmental factors (such as weather condition), and individual factors (such as body mass index, walking speed, and calories to burn). There is currently a void in the literature about routing services that consider walking and health together in multi-modal transportation.

3 BACKGROUND

3.1 Calorie Estimation

The American College of Sports Medicine (ACSM)[2] has investigated the amount of calories burned (energy expenditure) for several activities (e.g., walking, running, and stepping). The result of this investigation is an equation for walking which is adopted for the work in this paper. The ACSM walking equation (Tharrett et al. 2012) expresses walking energy expenditure as:

$$EE = (0.1 \cdot S + 1.8 \cdot S \cdot G + 3.5) \cdot BM \cdot t \cdot 0.005 \quad (1)$$

where

EE is walking energy expenditure (kilocalories)

S is walking speed (meters/minute)

G is grade (slope) in decimal form (e.g., 0.02 for 2% grade)

$BM$is traveller's body weight (kilograms)

t is walking time (minutes)

Eq. 1 is based on the assumption that the traveller walks at a constant speed during the time *t*, and the slope *G* is homogeneous. The equation is only accurate for the speed between 1.9 and 3.7 miles per hour (51-99 meters per minute) (Glass et al. 2007). To ensure slope homogeneity, a walking path may be split into n walking segments where each segment has homogeneous slope. This will result in the total energy expenditure (EE_{total}) for all the walking segments as:

$$EE_{total} = \sum_{i=1}^{n} EE_i \quad (2)$$

where EE_i is the energy expenditure of the *i*[th] segment, estimated by Eq. 1. The *i* subscript in Eq. 2 indicates that each segment may have a different walking speed, walking time, and slope.

3.2 Multi-criteria Optimization

Multi-criteria optimization has been used in many areas such as economics and engineering. Multi-criteria optimization (also known as multi-objective optimization) is "the process of optimizing systematically and simultaneously a collection of objective functions" (Marler and Arora 2004). The objective functions are formulated to quantify the solution of a decision problem based on the defined objectives. For example, consider a decision problem where a traveller may want an optimal walking path such that it: (1) can help burn around 40 kilocalories, (2) has no downhill slopes greater than 5%, (3) allows 2-2.5 miles per hour (54-67 meters per minute) walking speed, and (4) has least walking time. Considering these preferences, there are four objective functions in this example, one for calories burned, one for slope calculation, one for walking speed, and one for walking time, which are used for path optimization. The path optimization using the objective functions f_i follows the form:

$$\min_{p \in \boldsymbol{P}} \left(f_1(p), f_2(p), \ldots, f_n(p) \right) \quad (3)$$

$f_i(p)$ is the *i*[th] objective function;
$i = \{1,2, \ldots, n\}$; $n \in \mathbb{Z}$ and $n > 1$

Eq. 3 indicates that among all path alternatives (in the set $\boldsymbol{P}$), the optimal path is the one which is minimum with respect to the objective functions $f_1(p)$ to $f_n(p)$. Note that in cases of conflicts among some criteria, a trade-off is needed and a different path may be chosen as optimal. Such a trade-off among criteria can be controlled using the *weighted-sum method* which allows travellers to control the contribution of each objective function through the weight factors. In the weighted-sum method, each criterion is assigned a weight factor value, and the sum of all weight factors has to be a constant (usually 1). The larger the weight factor value, the more contribution to the final weighted-sum value. The optimization problem based on the weighted-sum method can be formulated as:

$$\min_{p \in \boldsymbol{P}} \sum_{i=1}^{n} \lambda_i * Norm_i(f_i(p)) \quad (4)$$

where $\boldsymbol{P}$ is the set of path alternatives

f_i is the *i*[th] objective function

λ_i is the weight factor for the objective function f_i

$Norm_i$ is the *i*[th] normalizing function

$i = \{1,2, \ldots, n\}$; $n \in \mathbb{Z}$ and $n > 1$

Eq. 4 is used to find optimal path alternatives in which various objective functions are homogeneously combined and normalized.

3.3 Multi-modal Transportation Model and Routing

In general, transportation refers to a means for

[2] http://www.acsm.org/about-acsm/

carrying passengers or goods from one location to another. In the context of this paper, transportation refers to the traveling of people between locations by vehicles or on foot. Transportation can be classified into uni-modal, where only one mode of transportation (e.g., walking, driving) is involved or multi-modal, where more than one mode of transportation (e.g., driving and walking) are involved. Trip refers to traveling from an origin to a destination. Trip can be uni-modal or multi-modal. Path is a possible physical connection between origin and destination for the purpose of traversing by uni-modal or multi-modal transportation. There could be multiple possible paths for a trip, and travellers usually choose the one they consider optimal based on one or more criteria. Finding an optimal path requires a transportation network which, in addition to geometry of the infrastructure, contains topology of the transportation infrastructure (e.g., road, bridge, tunnel, intersection, and sidewalk).

Transportation networks are commonly modelled as graphs of nodes and links. Each node represents a location where travellers must make a traversing decision (e.g., turn left/right, get on/off vehicle, switch between modes) and a link connects two nodes representing traversable passage (e.g., road segment, sidewalk segment). Usually each link is assigned a cost between its start and end nodes. Example costs are distance, time, expense, air pollution, and slope. Transportation networks suitable only for one mode of transportation are uni-modal, and a multi-modal network is formed by combining different uni-modal networks with designated existing or new nodes or links for switching between them.

In this paper, a multi-modal network is formed by combining a non-vehicular network (pedestrian network) and a vehicular network. A pedestrian network is a type of transportation network involving only walking modality. A vehicular network is a type of transportation network associated with vehicular modalities which include, but are not limited to, personal cars and buses. Example vehicular networks are road networks (for personal cars) and bus networks. The proposed multi-modal network requires “walking transfer” nodes that facilitate switching between the pedestrian network and the vehicular network. An example of how walking transfer is used is as follows. Suppose a traveller wants to travel from home to a meeting location in downtown by taking three modes of transportation: driving, walking, and riding. The traveller can drive from home to a parking lot and then walk to a bus stop to take a bus to the meeting location (assuming walking from the bus stop to the meeting location is feasible). For the driving-walking transfer, a node (v_i) representing a parking lot (which can be reached by car and on foot) is required. For the walking-riding transfer, a node (v_j) representing a bus stop (which can be reached on foot and by bus) is required. In practice, the criteria for choosing nodes v_i and v_j are based on traveller’s preferences. For example, suppose the traveller wants to avoid expensive parking fee in a downtown area and less expensive parking lots are available just outside of that area. In this case, the total sum of parking fee and bus fare should be less than the parking fee in downtown. Furthermore, the criteria for choosing the parking lot and the bus stop may vary depending on the context. For instance, the next day, the same traveller may want to increase physical activity to burn some calories through a brisk walk. For this, walking transfer nodes that increase walking distance between the parking lot and the bus stop (and/or between the bus stop and the destination) are of high priority. The problem of finding appropriate walking transfer nodes will become more complex if the traveller, in addition to the physical activity criterion, prefers to minimize parking fee and bus fare. All these considerations indicate that walking transfer plays an important role in multi-modal trips.

4 Route2Health ARCHITECTURE

Route2Health is a service designed based on four principles. First, it must support both uni-modal transportation and multi-modal transportation. This means that Route2Health recommends a multi-modal path between a pair of origin-destination locations only if an optimal walking path is not feasible. Second, it must take into account individual preferences in finding optimal paths. Third, the objective functions must be normalized so that they can be homogeneously combined and simultaneously optimized. Last, it must allow travellers to prioritize criteria to find personalized paths. Figure 1 shows the architecture of the Route2Health service which is composed of six components: (1) Walking Transfer Selector, (2) Vehicular Path Alternative Generator, (3) Walking Path Alternative Generator, (4) Path Combiner, (5) Objective Function Normalizer, and (6) Multi-Criteria Optimizer. Walking Transfer Selector is the component that takes as input origin, destination, and personal walking distance limit. Based on the inputs, Walking Transfer Selector would find all possible feasible walking transfers. Then based on the origin, the destination, and the identified walking transfers, the relevant walking path alternatives and vehicular path alternatives are computed by Walking Path Alternative Generator and Vehicular Path Alternative Generator, respectively. The path alternatives of the two modes are then combined into a complete path alternative by the Path Combiner. In the Objective Function Normalizer, the path alternatives are quantified using objective functions, and the outputs from the objective functions are normalized. The normalized values are then optimized by the Multi-Criteria Optimizer to obtain the final solution (optimal path).

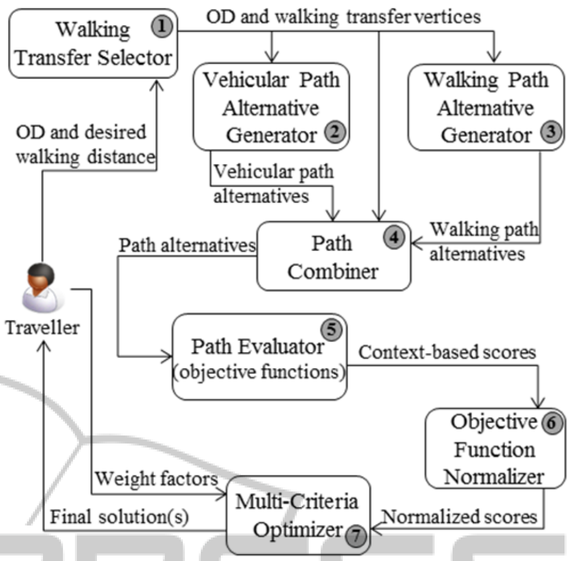

Figure 1: Route2Health architecture.

5 Route2Health PROTOTYPE

5.1 External Data and Services

Route2Health relies on a number of external data and services (listed in Table 1) for its computation. Google Directions API is used to implement the Vehicular Path Alternative Generator and Walking Path Alternative Generator components. Google Directions API provides up to three alternative paths (ordered by their estimated travel time) between a given pair of origin-destination locations. The paths retrieved from Google Directions API are evaluated as path alternatives. Google Elevation API is used to retrieve elevations along the walking path to calculate slopes of walking segments.

Table 1: External data and services used by Route2Health.

Information retrieved	Services
Based map	Google Maps API
Street address of a location	Google Geocoding API
Parking lot and bus stop locations	Google Places API
Driving and riding paths	Google Directions API
Walking paths	Google Directions API
Elevations along walking path	Google Elevation API

5.2 Route2Health Algorithm

The outcome of Route2Health is an optimal walking path for each trip request, where walking is either the only mode or one of the two modes of transportation. An algorithm was developed to compute optimal walking paths (see Figure 2). The inputs to the algorithm are an origin, a destination, body weight, walking distance, and the desired mode of vehicular transportation (driving or riding). Walking transfer nodes, located within an acceptable walking distance, are retrieved and used for vehicular and walking path computation. In the absence of walking transfer nodes that satisfy the requested walking distance, the algorithm computes only feasible walking paths that connect the origin and the destination. If walking transfer nodes (parking lots or bus stops) are found, the associated vehicular paths (driving or riding) are computed.

Once vehicular and walking paths are computed, the results (walking paths and vehicular paths) are combined to form a multi-modal path linking the origin, walking transfer nodes, and the destination. The number of walking transfer nodes determines the number of walking path alternatives. Once all walking path alternatives are identified, based on Eq. 1, the calorie burns for each walking path alternative is estimated. Slope of each segment of a walking path is estimated by using high-resolution Digital Elevation Model (DEM) data. Walking speed is provided by the traveller, or could be calculated based on walking path distance and estimated duration of walking. For each optimal path, path geometry, travel distance, travel time, and estimated calories burned are presented to the traveller.

5.3 Route2Health Application

A web-based prototype application was developed to demonstrate the Route2Health concept. The application’s interface features two panels (Figure

3), map panel (the left panel) and parameter inputting panel (the right panel). Through the parameter inputting panel, the traveller specifies profile and preferences including body weight, walking speed, walking distance limit (round trip), and preferred transportation modes (i.e., driving-walking or riding-walking). In the current version of the prototype, walking close to destination is implemented. This means that driving-walking involves driving from origin to a parking lot then walking to the destination, and riding-walking involves riding (bus) from origin to a bus stop then walking to the destination. If the traveller does not specify walking speed, the application will calculate the speed based on the walking path distance and duration retrieved from Google Directions Service. Based on the requested walking distance limit, either parking lots or bus stops (depending on the preferred mode within a walking distance limit) will be identified and used for path alternatives computation. Once all parameters are included, path alternatives (up to 20 in the current version of the prototype) are computed and listed. For each path alternative, a link to detailed information, such as travel distance, travel duration, and estimated calories burned, is provided. By clicking on the link, the detailed information will appear in the table in the results section and the associated path is displayed in the map panel.

Figure 4 shows two optimal driving-walking paths (P1 and P2) and Figure 5 shows two riding-walking paths (P3 and P4) between origin (A) and destination (B). The travel distance, travel duration, and estimated calories burned for each path are summarized in Table 2. In these examples, the round trip walking distance limit is set to 3.0 miles (around 1.5 miles each way). For driving-walking, P2 contains a better one-way walking distance than P1 (1.45 miles versus 1.14 miles) and requires only one minute longer than P1 (44.6 minutes versus 45.5 minutes) to travel. For riding-walking, P3 and P4 require almost the same total travel time (75.0 minutes and 75.8 minutes), but P3 can help burn 170 kilocalories for 1.58 miles walking distance which is much better than P4 which helps burn 111 kilocalories for 1.09 miles.

Another scenario is when the origin and destination are close to each other. Figure 6 shows traveller's request for a riding-walking path (with walking distance limit set at 3.0 miles), but since Route2Health finds that the walking path is only 1.2 miles long, the walking path is recommended instead of a riding-walking path.

In case of a destination located within a downtown area (which usually has high road density and large number of parking lots), the number of driving-walking path alternatives will be large. However, in a hilly area, like downtown in Pittsburgh, the computed path alternatives are not very different. In Figure 7, there are 16 parking lots suggested by Route2Health, but the walking paths from the 16 parking lots merge into only three paths close to the destination which is located in downtown Pittsburgh. The reason for this may be alluded to the fact that the walking paths, computed by Google Directions Service, are chosen based on their flatness. The background terrain map in Figure 7 shows least variation in elevation on the paths in the north-east direction. The flat walking paths seem to be reasonable in general, but, as discussed in the previous section, some people may prefer more challenging (hilly) paths than flat paths. The example also confirms the claim that the existing routing services do not fully support the concept of Route2Health.

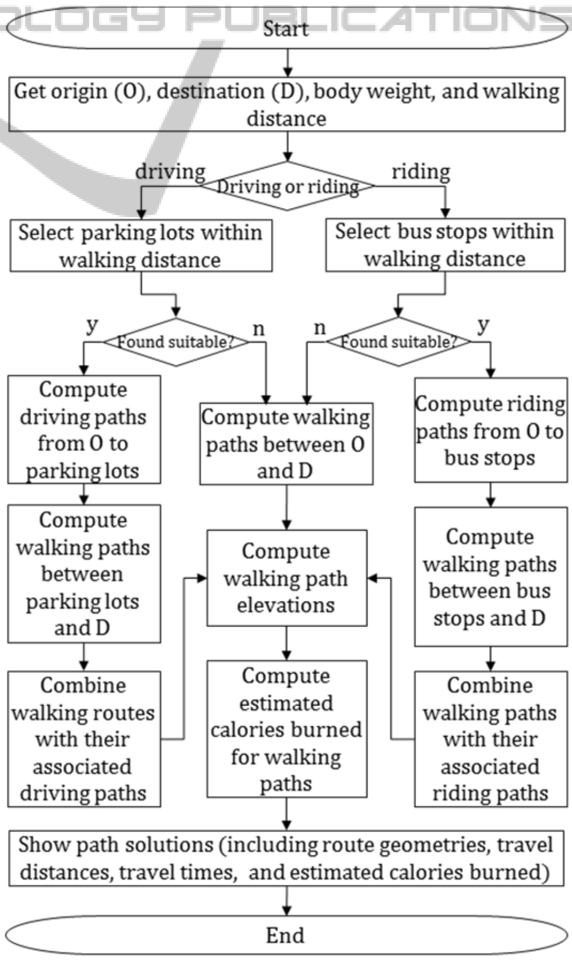

Figure 2: Route2Health algorithm.

Table 2: Path alternatives summary.

Path	Mode	Distance (miles)	Duration (minutes)	Calories (kilocalories)
P1	Drive	5.90	15.2	N/A
	Walk	1.14	29.4	131
	Total	7.04	44.6	131
P2	Drive	5.73	13.4	N/A
	Walk	1.45	32.1	143
	Total	7.18	45.5	143
P3	Ride	5.19	36.9	N/A
	Walk	1.58	38.1	170
	Total	6.77	75.0	170
P4	Ride	5.97	50.9	N/A
	Walk	1.09	24.9	111
	Total	7.06	75.8	111

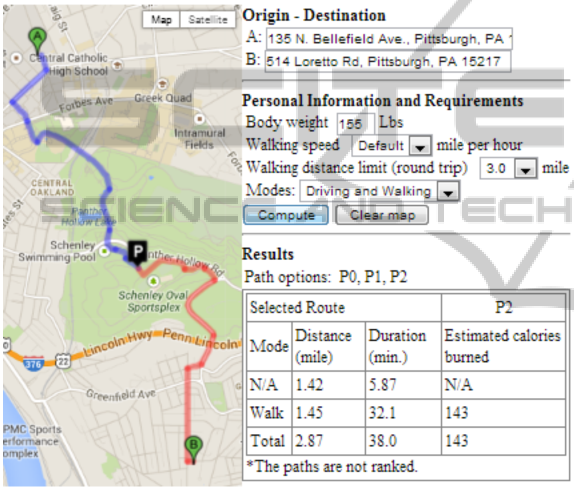

Figure 3: Route2Health user interface.

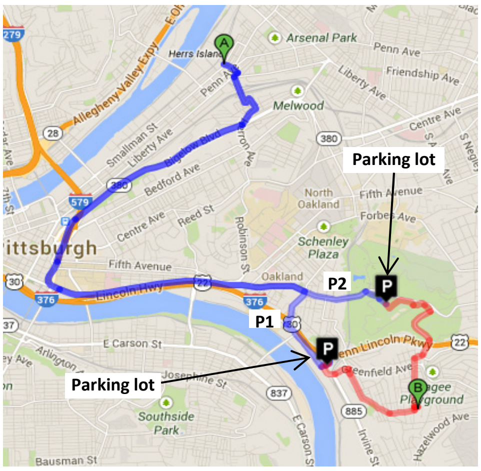

Figure 4: Driving-walking paths from A to B.

For driving-walking, when the destination is close to an area with a large number of parking lots (such as a downtown area), the parking lots selected

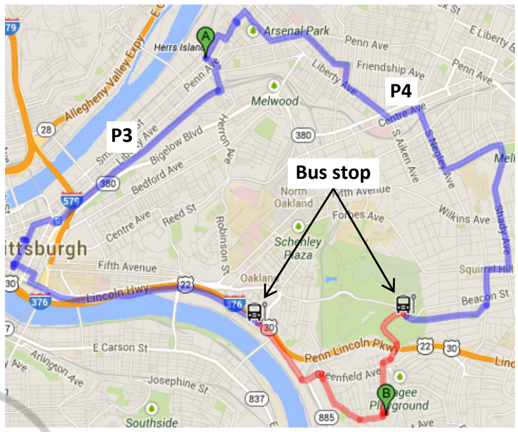

Figure 5: Riding-walking paths from A to B.

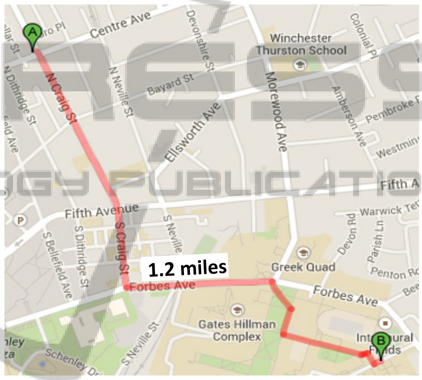

Figure 6: Walking path for destination close to origin.

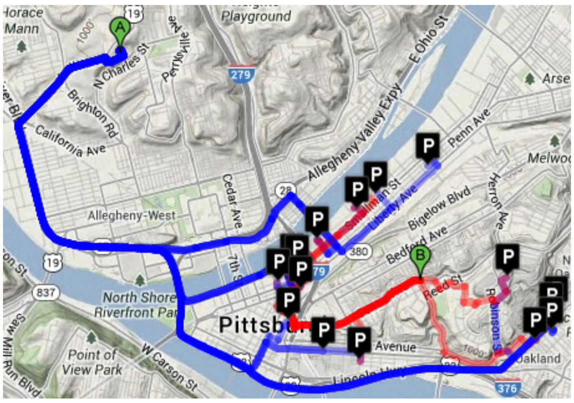

Figure 7: Multiple parking lots in Pittsburgh downtown area.

by Walking Transfer Selector may spatially cluster together within the area. Figure 8 (upper map) shows an example of the aforementioned scenario. One problem with clustered parking lots is the possibility of impractical path alternatives. In Figure 8 (lower map), the parking lots cluster on one side of the river, while the origin and destination are both

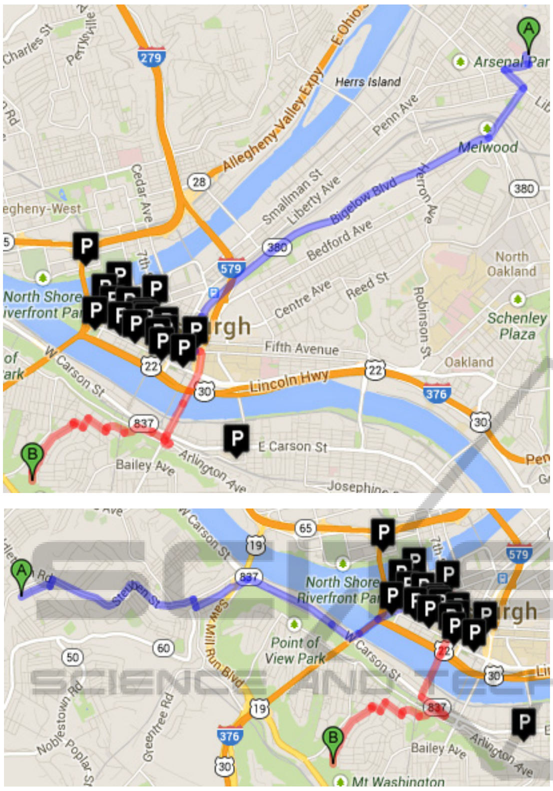

Figure 8: Parking lots cluster in downtown area.

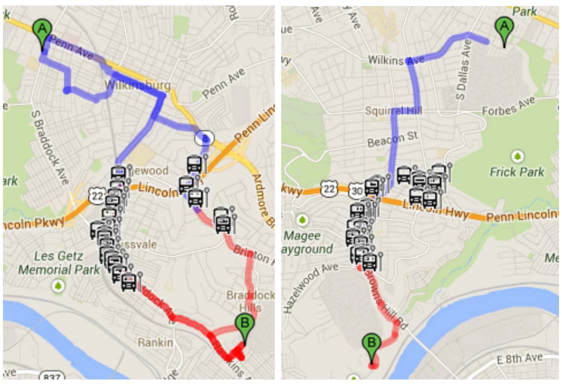

Figure 9: Cluster of selected bus stops along roads.

located on the other side. This means that regardless of the paths the traveller chooses, the river must be crossed by car, the car must be parked on the other side of the river, and the river must be crossed on foot to the destination. Similar situations may occur with bus stops. In Figure 9, as the area of interest has a large number of bus stops, most of the candidate bus stops linearly cluster just right next to each other on the same road. From traveller's perspective, the linear sequence of bus stops is representing the same riding path. The two examples (Figure 8 and Figure 9) support the claim (discussed in the previous section) that walking transfer plays an important role in multi-modal transportation trip planning.

6 SUMMARY AND FUTURE WORK

Route2Health, as a new approach helping increase physical activity by considering walking always as one mode in multi-modal transportation trip planning, is presented. The algorithms for computing a walking session for each trip along with the components of the Route2Health service are discussed. A prototype Route2Health was developed and sample scenarios were described.

Two directions for future research are evaluation and deployment of Rout2Health. Evaluation could be based on pre- and post-testing analysis to determine the level of physical activity (indicated by the number of trips with walking sessions) before and after using Rour2Health. Deployment of Route2Health as a web application accessible through both desktop platforms and mobile devices is considered. The application will be used for both trip planning and real-time navigation. With position and speed obtained through GPS sensors embedded in smart phones, a progress report on position, speed, time, distance, and calories can be provided to the traveller in real time and more accurately. Trips, once completed, along with relevant parameters, can be stored for performance assessment of walking over time. The mobile version can also be integrated with existing physical activity monitoring devices such as BodyMedia[3], FitBit[4], Nike+FuelBand[5], and Jawbone[6]. These devices are wearable sensors that help monitoring physical activities such as walking, running, sleeping, and energy expenditures. Data from such sensors can provide more accurate walking speed and energy expenditures to Route2Health.

REFERENCES

Bassett Jr, D. R., Pucher, J., Buehler, R., Thompson, D. L., & Crouter, S. E., 2008. Walking, cycling, and obesity rates in Europe, North America, and Australia. *J Phys Act Health*, *5*(6), 795-814.

[3] http://www.bodymedia.com/explore.html
[4] http://www.fitbit.com/
[5] http://nikeplus.nike.com/plus/what_is_fuel/
[6] https://jawbone.com/

Besser, L. M., Dannenberg, A. L., 2005. Walking to Public Transit Steps to Help Meet Physical Activity Recommendations. *American Journal of Preventive Medicine*, 29 (4). 273-280.

Bit, A. K., Biswal, M. P., & Alam, S. S., 1992. Fuzzy programming approach to multicriteria decision making transportation problem. *Fuzzy sets and systems*, 50(2), 135-141.

Edwards, R. D. (2008). Public transit, obesity, and medical costs: assessing the magnitudes. *Preventive Medicine*, 46(1), 14-21.

Das, S. K., Goswami, A., & Alam, S. S. (1999). Multiobjective transportation problem with interval cost, source and destination parameters. *European Journal of Operational Research*, 117(1), 100-112.

Glass, S., & Dwyer, G. B. (Eds.). (2007). *ACSM's Metabolic Calculations Handbook*. Lippincott Williams & Wilkins, 19 & 26.

Himann, J. E., Cunningham, D. A., Rechnitzer, P. A., & Paterson, D. H., 1988. Age-related changes in speed of walking. *Med Sci Sports Exerc*, *20*(2), 161-166.

Karimi, H. A., Peachavanish, R. and Peng, J., 2004. Finding Optimal Bus Service Routes: An Internet-Based Methodology to Serve the Transit Patrons. ASCE *Journal of Computing in Civil Engineering*. 18(2), 83-91.

Li, Q., & Kurt, C. E., 2000. GIS-based itinerary planning system for multimodal and fixed-route transit network. *In Proceedings of the MID-Continent Transportation Symposium*, 47-50.

Li, J. Q., Zhou, K., Zhang, L., & Zhang, W. B., 2010. A multimodal trip planning system incorporating the park-and-ride mode and real-time traffic/transit information. *In Proceedings of the 17th ITS World Congress*.

MacDonald, J. M., Stokes, R. J., Cohen, D. A., Kofner, A., & Ridgeway, G. K., 2010. The effect of light rail transit on body mass index and physical activity. *American journal of preventive medicine*, 39(2), 105-112.

Marler, R. T., & Arora, J. S., 2004. *Survey of multi-objective optimization methods for engineering. Structural and multidisciplinary optimization*, 26(6), 369-395.

Modesti, P., & Sciomachen, A., 1998. A utility measure for finding multiobjective shortest paths in urban multimodal transportation networks. *European Journal of Operational Research*, 111(3), 495-508.

Morabia, A., Mirer, F. E., Amstislavski, T. M., Eisl, H. M., Werbe-Fuentes, J., Gorczynski, J., & Markowitz, S. B., 2010. Potential health impact of switching from car to public transportation when commuting to work. *Journal Information*, 100(12).

Pucher, J., Buehler, R., Bassett, D. R., & Dannenberg, A. L., 2010. Walking and cycling to health: a comparative analysis of city, state, and international data. *American Journal of Public Health*, 100(10), 1986-1992.

Rehrl, K., Bruntsch, S., & Mentz, H. J., 2007. Assisting multimodal travelers: Design and prototypical implementation of a personal travel companion.*Intelligent Transportation Systems, IEEE Transactions on*, 8(1), 31-42.

Sallis, J. F., Frank, L. D., Saelens, B. E., & Kraft, M. K., 2004. Active transportation and physical activity: opportunities for collaboration on transportation and public health research. *Transportation Research Part A: Policy and Practice*, 38(4), 249-268.

Sharker, M., Karimi, H. and Zgibor, J., 2012. Health-Optimal Routing In Pedestrian Navigation Services. *ACM SIGSPATIAL HealthGIS'12*. Redondo Beach, CA, 1-10, ACM.

Tsolkas, D., Passas, N., Xenakis, C., Papataxiarhis, V., & Tsetsos, V., 2012. Busfinder: a personalized multimodal transportation guide with dynamic routing. *In Informatics (PCI), 2012 16th.Panhellenic Conference on*, 25-30, *IEEE*.

Tharrett, S. J., & Peterson, J. A. (Eds.), 2012. *ACSM's health/fitness facility standards and guidelines. Human Kinetics*.

U.S. Department of Health and Human Services, 1996. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.