BUILDING A COMMUNITY INFORMATION SYSTEM FOR SUPPORTING DISABLED BUS RIDERS AND LOCAL BUSINESSES

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Abstract: This paper discusses the implementation of one type of information system for the New York City bus transit service, as a case study to provide value-added transportation services for people with impaired mobility. Information technology is a key tool for finding flexible transportation services, especially for disabled people. Useful information supplies psychological reassurance to these vulnerable people to make them feel more safe and secure. Residents in metropolitan areas increasingly rely on the convenience of public transportation, and they are becoming used to exchanging information relevant to their regional community in on-line settings. The improvement to transit accessibility needs the exact same type of the cooperation between transportation companies, local business, and residents. The widespread use of mobile wheelchairs has a socioeconomic impact. The significance of this research for the longer-term goals lies in its implications for adaptation of this kind of intelligent model into future welfare or assistive activities.

1 INTRODUCTION

The number of people who are mobility impaired by age or disability is increasing at a dramatic rate. It is no longer an insignificant or silent part of the society. The 2007 report published by the Department of Economic and Social Affairs, Population Division, of the United Nations estimates the percentage of aged people, those over 60 years old, will grow from the current 11% of the world population to 15% in 2025 and to 22% by the year 2050. When considering developed nations only, the report projects this group will constitute nearly a third of the population (United Nations, 2007). Moreover, the 2007 fact sheet published by the International Day of Disabled Persons reports that around 10% of the world's population today is living with some disability. This means that by the year 2025, it is likely that around 1/5 of the world's total population will need economic and social benefits as well as some kind of artificial perambulatory assistance in their daily lives.

The United States will certainly face challenges as people live longer and in better health. Projections by the U.S. Census Bureau estimate the number of persons ages 65 and over will grow to almost 40 million by the year 2010 (Jones and Sanford, 1996). Today, more than 4 million people in the United States are over the age of 85 and about 60,000 topped age 100. By 2020, the Census Bureau further estimates that 7 million to 8 million people will be over age 85 and 214,000 will be over age 100. As life expectancy rises and modern medical technology improves, there is a growing interest in building more advanced support structures for society. In particular, a desire to enhance quality of life with advanced wheelchair designs is a steadily growing phenomenon (First Research, 2007). A strong demand for a less restrictive environment is also on the rise, such as barrier-free accesses, safer and more convenient route selections, more transportation alternatives, and so on.

The motivation for this research is to address a fundamental question in the handling of these challenging problems. Today's transportation infrastructure is missing a piece in the context of wheelchair mobility. Imagine a great influx of people in wheelchairs having to navigate through crowded

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aisles and streets. Sidewalks can be harmful or even impassible by those wheelchairs. Correcting these issues universally may require reconsideration of many issues, including roadway traffic, parking space, and accident handling, from both engineering and even legal perspectives. In our view, however, today's information systems can be easily, quickly, and cheaply expanded to enable a dramatic improvement in transportation accessibility by incorporating a community supported web service so users can objectively evaluate whether or not the public transportation services available address their individual needs. The focus of our study here is to call for wide-scale community support towards the deployment of an information system that enables a more future oriented view of this class of services.

Specifically, this paper presents one case study of such a deployment as a means of promoting grassroots activities supporting handicapped people. We discuss the development of one type of on-line database system based on the New York City bus transit service. This is to demonstrate key roles of the information technology and community service, not only in guiding travel route, but also in understanding physical situations in the movement and actual environment of the wheelchair. The government offices and private sectors in the New York metropolitan area are continuously making systemic reforms to ensure that services and supports for people with disabilities are available in the most integrated setting (CIDNY, 2007). The priorities are set for assisting with access to health care, benefits, employment, housing, and education (MISC, 2006). For instance, `NYHousingSearch.gov` provides a free on-line public service to allow disabled people to locate available housing that meets their individual and family needs at a rent they can afford (CPANYS, 2007; Paterson, 2009; Appel, 2007). This effort has been supported by grants to promote effective and enduring improvements in community-based long-term care and support systems for seniors and people with disabilities. The question that needs to be answered is the efficacy of the same approach in transportation issues.

Information resources for the disabled need improvement. The government usually requires transportation service providers, such as taxis, limousines and shuttle services, to purchase accessible vehicles or otherwise ensure that they have the capacity to serve people with disabilities (NYAIL, 2009). Yet limited awareness of these services or lack of confidence in their reliability may discourage use. So limited availability of accessible transportation services remains a major barrier faced by individuals with disabilities throughout the state, often leading to unemployment, the inability to access medical care, and isolation from friends, family, and full community participation (CIDNY, 2007). For the proposed system, it is vital that the people who accept cooperation and evolution openly share with the living community by providing useful information. As more information becomes available and uploaded to the database, the scale and magnitude of support will grow. We will describe ideas on how to involve activities at the local level in this regard. Non-handicapped people need to make a greater effort to educate themselves about disability issues or risk being unprepared for the coming increase in the mobility impaired population. This community can play an important role in providing a respectful environment for the discussion and exploration of these issues. Paired with the primary motive of making it easier for the disabled to access reliable transportation, this system stands to benefit all segments of society.

Paper Organization. The rest of this paper is organized as follows: Section 2 explains our motivation for this research and scope of our work. Section 3 discusses our case study of the implementation of the NYC bus transit service for disabled riders, and Section 4 summarizes our approach for extending this system to incorporate community-support and business incentives. Section 5 discusses related work, and Section 6 concludes our work presented in this paper.

2 WHY DO WE NEED COMMUNITY SUPPORT?

The demand for wheelchairs and other mobility devices in the U.S. is projected to increase 5.0% per year through 2010 to over $3 billion (Supplier Relations, 2007). According to the 2005 Survey of Income and Program Participation report (Brault, 2008), 27.4 million people of age 15 and older (11.9% of U.S. population) had difficulty with ambulatory activities of the lower body, thus required mobility assistance. About 22.6 million people (9.8%) had difficulty walking a quarter of a mile, and 12.7 million were not able to perform this activity. About 21.8 million people (9.4%) had difficulty climbing a flight of stairs, and 7.4 million of them were not able to do it at all. Roughly 3.3 million people (1.4 %) used a wheelchair or similar device, and 10.2 million (4.4 %) used a cane, crutches, or walker to assist with mobility.

Advances in electronic controls, latter-generation secondary batteries, light-weight construction materials and other areas are also stimulating the growth in both the wheelchair- and non-wheelchair-related segments of the personal mobility device industry. Technology for the computerized aid, care, and support of people in mobile wheelchairs is evolving rapidly. Although it is in a branch that spans autonomous process control, intelligent engineering systems, and information management, there exists no widely accepted practice or reference model that leads to the integration of these technical elements into mass transportation systems (NCODH, 2005). This research aims to explore several key issues in implementing assistive infrastructures and surrounding information systems that host macro control for the smooth and safe navigation of mobile wheelchairs in the public transportation environment (Kawaguchi et al., 2008a; Kawaguchi et al., 2008b; Kawaguchi and Chan, 2009; Kawaguchi et al., 2009).

Today's physical infrastructure shows a significant transformation that makes it more accessible to wheelchair users. This transformation has been initiated by legislative reform and longstanding social momentum to include people with disabilities as more active participants in the society (ILO, 2007). Despite these efforts, many aspects remain uncertain as to how to best address these issues in both private organizations and the local community. For the last several years, the metropolitan community in the U.S. has become increasingly aware of the need to get more involved in supporting vulnerable people. Noticeable changes are visible in many cities and parts of the world, such as the installation of elevators, transit lifts, and wheelchair ramps in public areas. These improvements are increasingly legally required for access to public areas such as city streets, public buildings, and restrooms, thus allowing people in wheelchairs and with other mobility impairments to use public sidewalks and public transit more easily and safely. The efforts presented in this paper share the same spirit of this ongoing change and intelligent design movement.

The importance of community support will inevitably grow, which will in turn stimulate the development and deployment of an information product and a practice including a wide range of activities spanning design, instrumentation, computer integration, process and device control, and manufacturing (Kawaguchi et al., 2008a; Kawaguchi et al., 2008b). The successful implementation mandates not only interdisciplinary effort across the industrial and academic research spectrum, but also participation and cooperation of wheelchair users, transportation companies, disability advocates, and voluntary experts in public. Overall, it is a continuous process in which users in all parties participate actively from the preliminary study stage to the post evaluation stage, so that the knowledge and experience obtained from them can be applied to the next level of innovation (Ministry of Land and Transport, 2006).

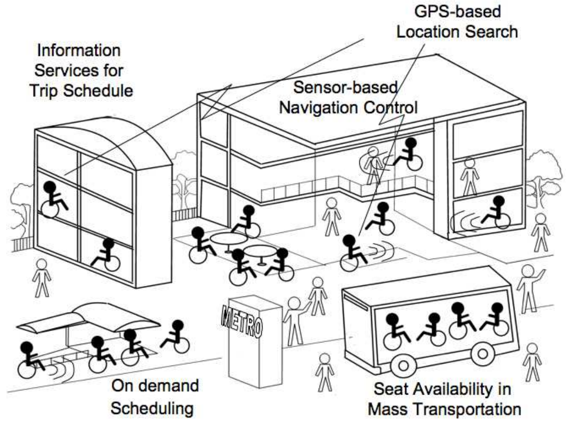

Figure 1: A vision of mobile wheelchair support in the coming age (Kawaguchi et al., 2008a).

Information technology is a key for providing flexible transportation services and increased choice for the users (see Figure 1). In addition, useful information supplies psychological reassurance to vulnerable people to make them feel more safe and secure. A federal civil rights procurement law in the U.S. requires electronic and information technology to be accessible to people with disabilities. Flexible services are brought by a wide variety of innovative information services now in use increasingly in many countries. For instance, the presence of ubiquitous network technology that consists of IC tags, wireless tags, RFID tags, and other communication equipment such as portable information terminals makes it possible for elderly people and handicapped people to move freely and independently. The use of more economical PHS communication network generally available in Asian countries can afford precise tracking of wheelchairs moving in and around dense urban areas like hospitals, libraries, and museums. GIS technology that allows conversion of geographical information into electronic form also facilitates the wide-scale integration of navigation assistance and tracking capability into various telecare information systems.

Up-to-date information services such as availability, route guidance, cost, efficiency, and safety must be always available to improve the overall level of public transportation including railroad, bus, airline, and shipping. Traffic-aware routing based on portable GIS device is a new area in vehicle industries. At the same time, traditional internet-based software that can handle scheduling, dispatching and reservation, such as Ecolane DRT, PASS and NaviTrans, plays an important role to implement demand-responsive transportation schemes or flexible door-to-door paratransit service for wheelchair users.

3 BUS TRANSIT SERVICES FOR WHEELCHAIR RIDERS

The New York City Transit in the Metropolitan Transportation Authority network operates the world's largest fleet of buses (4,373 public buses), serving over 666 million people per year for New York City to sustain its economy and support projected growth (MTA Guide, 2006). These buses are equipped with wheelchair lifts in either the front or back entrance of the vehicle, and have a "kneeling" feature that lowers the front entrance to within inches of the ground for easy access by any customer with mobility impairments or difficulty using the front steps. The Tokyo Metropolitan Bus Systems in Japan, by comparison, maintain the second largest scale of fleet, but do not run this level of service with lift-equipped vehicles (see Table 1 for the projected improvement from Japanese government standpoint).

Table 1: Preset goals for the barrier-free implementations of Japanese public transportation (Ministry of Land and Transport, 2006).

Transportation Media	2003	2010
Railway cars	24%	30%
Non-step buses	9%	20-25%
Passenger ships	4%	50%
Airplanes	32%	40%

The bus system covers routes not served by the city subway system and outlying areas, and stops every 2 blocks on a nearly 24 hour schedule. The bus system is becoming the primary mode of transportation for wheelchair users living in the city. The city convention and visitors bureaus are offering guides that list wheelchair-accessible facilities. However, these brochures are rarely detailed enough to rely on and can't contribute to a full-scale mechatronics support for barrier-free accesses.

An on-line database system to facilitate the exchange of useful information among disabled bus riders and accessibility supporters in New York City is being built by our efforts. The system has a Web interface to find out the bus routing information on a trip from one point to another point in Manhattan. The capability beyond the "Trip Planner" web system (Trip Planner, 2009) implemented by the Metropolitan Transit Authority is to respond using a map with appropriate paths (sequences of bus rides) to be taken to reach the destination along with the roadside information of toilet options, coffee shops and restaurants accommodating wheelchairs, quick repair services for motor trouble and battery replacement, and purchases of wheelchair equipments, etc., on the selected route. The system works with the Google Maps API to create the visual interface, thereby giving a quick way to narrow down the user choice of accessible sporting and cultural events.

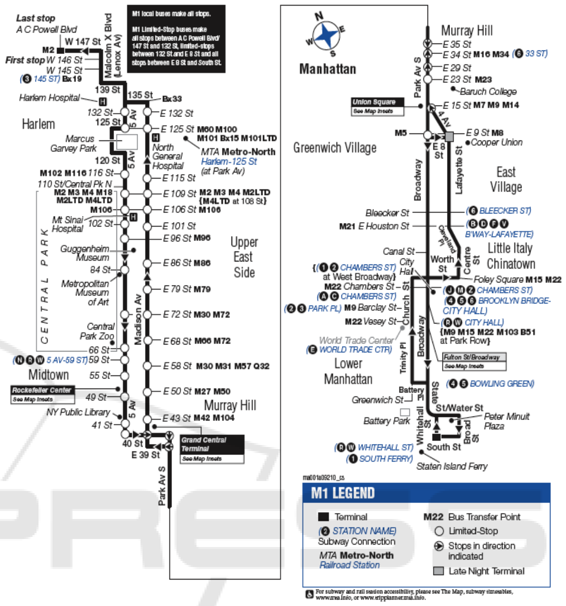

Figure 2: Manhattan Bus Line Map (duplicated from MTA NYC Transit official site).

3.1 Implementing a Prototype Search Service Application

A prototype system runs on a typical LAMP (Linux-Apache-MySQL-PHP) solution stack. The current release covers the major stopping points and transfer points of the MTA bus lines whose services are bound in areas of Manhattan (thus the search capability is limited within Manhattan). The information of such traffic points is hand-populated based on the bus schedules published by the MTA NYC (see Figure 2). Figure 3 shows a view of the system's interface—our periodic build can be accessed at http://wikiwiki.engr.ccny.cuny.edu/~akira/BusSystem.

A traffic point is a geographical location consisting of latitude and longitude. The point collection is structured as a directed graph in the database. As shown in Table 2, `buspoints` table holds latitude and longitude (double type) of the bus running points. Its ID field (smallint type) has a unique point number for a particular line (char(8) type). Some of the points

Table 2: MySQL tables representing bus services.

`buspoints table`

Line	ID	Ptype	Lat	Lng	Tag
M1	1	terminal,transfer	40.822	-73.938	W 147St & ...
M1	2	terminal	0.821	-73.936	W 146St & ...
M1	...	...	...	...	...
M1	33	transfer	40.731	-73.992	E 8th & ...
M1	34	terminal,transfer	40.730	-73.991	E 8th & ...

`busroute table`

LineFr	IDFr	LineTo	IDTo	Bound
M1	1	M2	null	null
M1	2	M1	3	south
M1	...	...	...	...
M1	34	M1	null	south
M1	34	M8	null	null

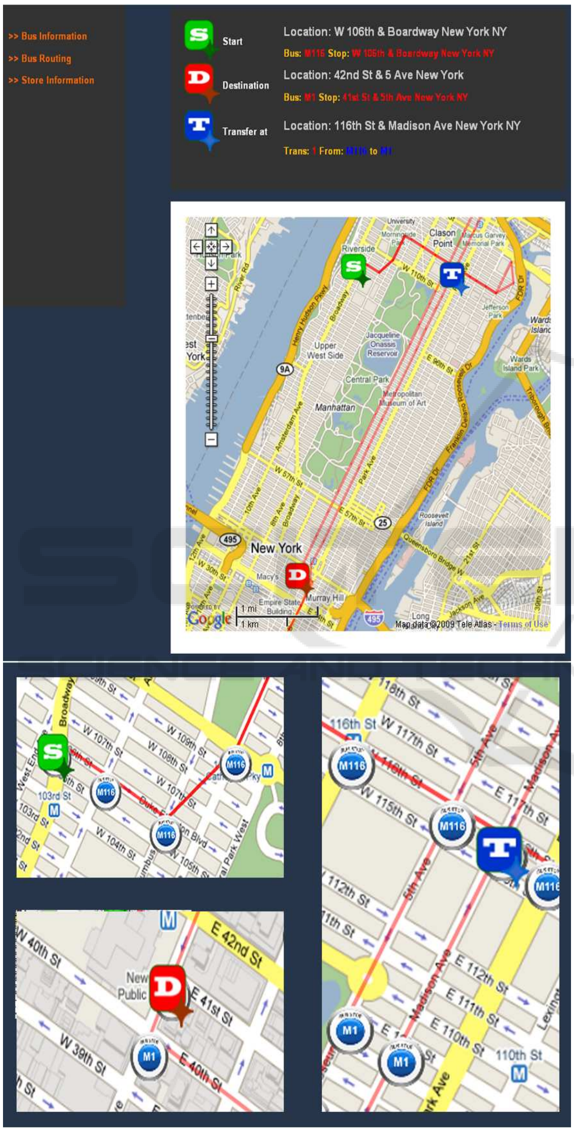

Figure 3: Manhattan bus routing search service system.

are of the type (set type) of terminal, transfer, or both. The tag field (varchar(60) type) is for the text address. Another `busroutes` table holds route information or a topological sequence such that one point leads to another point in each bus line. There can be multiple directions per line such as South and North, and East and West bounds, which can be expressed by a bound indicator (enum type). A transfer point is expressed using the name of the line for transfer.

A query transaction computes acyclic paths between start location and destination. The reachability set of a directed graph is a maximal set representing reachability from given starting points to other points in that graph. Notice that there can be combinations of starting points and ending points, each of which establishes a valid route in close proximity. This is because the user's inquiry is usually based on the addresses of the starting and ending points of a trip, not precise initial bus points. Therefore, the bus points approximating the trip must be found within a range of distance (choice of 1/2, 1/4, and 1/8 mile) from the specified addresses. Geocoder public service (http://geocoder.us) is used to find the latitude and longitude of the specified address. Accordingly, the bus points in the `buspoints` table within the requested distance can be found.

Our implementation of on-the-fly travel path computation is based on a *semi-naive evaluation* (Bancilhon and Ramakrishnan, 1986) employed in the recursive, bottom-up evaluation of logic programs (the algorithm can be realized by an iterative execution of SQLs). The problem to address is preventing explosive growth of the graph traversals. There can be multiple ways to complete the trip by hopping around different bus lines. Thus, various heuristic reductions of search space are devised, in particular, the elimination of moves ineffectual to reach the destination (e.g., south-bound transfer from north-bound trip).

The additional task is finding points of interest (eateries, drugstores, etc.) along each possible course of travel. See Figure 4 for the scheme of the computation. The points of interest are found within the excess (1/2, 1/4, and 1/8) of a mile outside the bounding box made out of each leg of bus movement. In Figure 4, two bus stops (line A and B) are found, and the areas enclosed by their neighboring bus stops can also be identified. All the found points are shown together with the bus route on the generated map. The entire procedure to process a user request is processed within a read-uncommitted transaction so as to minimize database overhead. The response time observed so far using a single quad-core based mid-range data server is less than several seconds, and is quite satis-

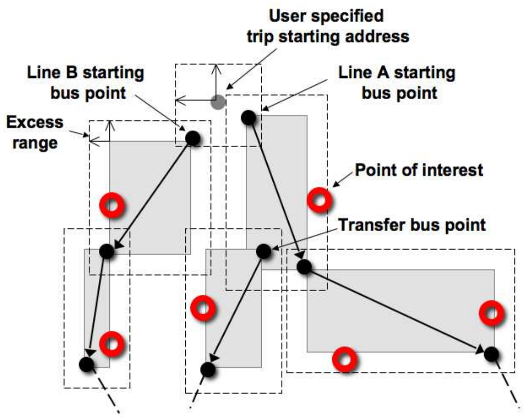

Figure 4: Finding points of interest.

factory.

4 COMMUNITY SUPPORT FOR VULNERABLE PEOPLE

For those aging or disabled people whose condition makes them unable to walk, advanced mobile wheelchairs provide many benefits, such as maintaining mobility, continuing or broadening community and social activities, conserving strength and energy, and enhancing their general quality of life. Particularly residents in metropolitan areas are increasingly utilizing the convenience of public transportation. Separately, they are becoming used to exchanging information relevant to their community in on-line settings. The accessibility improvement needs the exact same type of the cooperation between transportation companies, regional and local industry, and local residents: transportation companies, private business, public places, and any points of interest for residents such as restaurants, shopping centers, movie theaters, etc., must supply the accessibility information to a public database system, which in turn provides immediate retrieval for transportation and route selection, thereby giving great aids to realize macro-level control in wheelchair movement.

The Web interface of our system has this additional capability to accumulate community information in the form of a point of interest and/or assistive ability. The people in the metropolitan areas can register and augment categorized information in the database. Specifically, a person (e.g., restaurant owner) can contribute to the system by registering his/her item (e.g., restaurant) into a set of suitable categories (e.g., bathroom services, eatery, etc.). The registration is done by filling out the owner's identity (full name, contact address, phone, and email) as well as detailing the item to register and the category to classify. The information on the item includes name, address, phone, web URL, geo-position, capacity, up to 3 pictures, textual comment, and a link to the owner. The category can be chosen from those already in the database or newly created at the registration. There may be multiple categories to which the item needs to belong. For instance, restaurant can be in the categories of bathroom services and eatery.

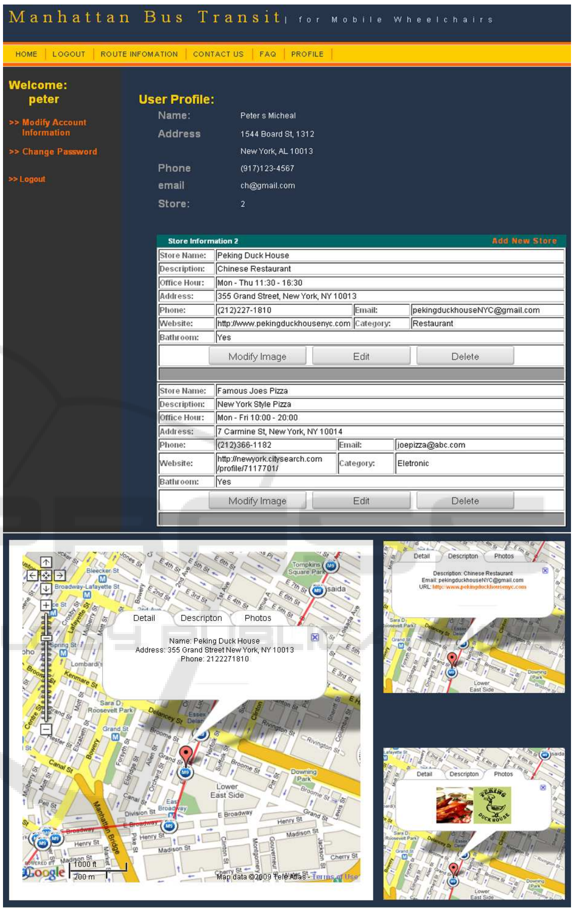

Figure 5: Finding interest points with bus line.

The registration of the item is not immediately reflected in the database, but becomes pending at first. An administrator of the system needs to inspect if the requested registration is valid or not. Email is generated to the owner right after the administrator's decision. Category classification is not static. The administrator can reorganize it by merging and splitting branches. The registered items whose locations are close to the suggested course of travel are selectively shown in the Google Map interface (see Figure 5).

5 RELATED WORK

The public acknowledgment of people with disabilities and progress toward enhanced care has developed in the last few decades along three parallel tracks of activities (Longmore and Umansky, 2001)—these are legislation spurred by the disability rights movement, barrier-free design to universal design movement, and advances in rehabilitation and assistive technology.

Universal design is a design paradigm that aims to reduce the physical and attitudinal barriers between people with and without disabilities. This concept emerged from barrier-free design principles and assistive technology. The former provides a level of accessibility for people with disabilities, and the latter enhances the physical, sensory, and cognitive abilities of those people (Orpwood, 1990). The concept of universal design gives a broad-spectrum of solutions that help everyone, not just people with disabilities, and it is now becoming one of the most important design elements that range in scale from product design to architecture and urban design, and from simple systems to complex information technologies (NCODH, 2005). The forthcoming transportation facilities are therefore likely to be in compliance with universal design principles.

Assistive technology (Cook, 2002) applies to devices that provide direct physical or mental aid to people with disabilities. The element closely tied to mobility and mechatronics support is a smart wheelchair (Simpson, 2005) or an augmentative mobility aid that accepts a variety of different controls tailored to the riders needs, and complements the riders efforts by expanding and interpreting their limited control commands to provide safe transit (CALL Centre, 1994). A smart wheelchair has a collection of sensors to work with several cognitive techniques similar to those developed in mobile robotics, but it is not necessarily acting autonomously because the aim is to complement and extend the user's abilities, not replace them.

The majority of the smart wheelchairs that have been developed to date have been tightly integrated with the underlying power wheelchair, thereby requiring significant modifications to function properly (Simpson et al., 2004). The forthcoming research on the extension of smart wheelchairs, enhanced with path-planning, behavioral learning, and cognitive capabilities will have a significant impact on the outcome of the mechatronics implementation. As an example, there is a study to systematically utilize and extend mechatronics-based assistive services, an emerging field devoted to engineering personal devices that enhance the physical, sensory, and cognitive performance of people with disabilities and help them function more independently in environments oblivious to their needs (Kawaguchi et al., 2008a; Kawaguchi et al., 2008b; Kawaguchi and Chan, 2009; Kawaguchi et al., 2009; Noda et al., 2009). This field lies as a support technology centered on mechanics, electronics, and computing. The mechatronics support in our vision is meant to emphasize a synergistic integration of the latest techniques in cross-disciplinary fields.

Paratransit is another mode of passenger transportation increasingly offered for handicapped commuters and travelers, which in general does not follow fixed routes or schedules, but typically uses vans or mini-buses for the higher flexibility of picking up or discharging passengers on request. Many vehicles are specially equipped with wheelchair lifts or ramps to facilitate access, thus allowing people with disabilities to have greater employment opportunities by providing transportation to and from their workplaces (Simon, 1997). A sub-sector of private business is on the rise to meet the growing interest in the paratransit strategy, but the cost for serving low-density areas and dispersed trip patterns do not balance with today's declining financial conditions, which may instead create an urgent need for public transit operators to maximize all available transportation resources.

6 CONCLUSIONS

The subject of this paper is a high-level discussion to address the problem of physical mobility in our society in the coming age. The issue has powerful effects on the living conditions of those with physical disadvantage who seek to maintain mobility, wish to continue or broaden community and social activities, conserve strength and energy, and enhance their general quality of life. The community-based approach outlined here is a basic framework to cope with the influx of vulnerable people in mobile wheelchairs. The concept of information sharing gives the opportunity to understand and promote any resulting benefits in broader developmental contexts.

An abundance of information is available and sharable through the computer medium. The ultimate goal of our on-going work is to make electric powered wheelchairs predict and avoid risky situations and navigate safely through the congested areas and confined spaces, by exchanging the terrain and location information in real-time. To accomplish a more future oriented view of this class of services, today's information systems must be expanded to incorporate the community support and to objectively evaluate whether or not the public transportation services fit the user's needs. The community-based approach we proposed encompasses these views and shares a common spirit with the universal design ideal.

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