Legged Wheelchair mobility?

Do you see any advantages and disadvantages of this idea? Where do you see the main difficulties in the realization of such idea?

Please concentrate on the main positive and week sides of such solution. Do you know any other ideas, projects, products, or research projects, which concern non-traditional way of mobility? Can any of these ideas be applied to the transportation of disabled and elderly people? Do you have any other ideas for indoor and outdoor transportation of people with disabilities?

You can refer to the paper of D. Browning "Legged mobility. A Wheelchair Alternative", which is below. Important here is not only your reading of the mentioned paper but also your personal opinion. I expect a lot of interesting suggestions.

Please do homework 5 no later than 19 June, 1 PM and submit it to the instructor.

Legged Mobility
A Wheelchair Alternative

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ABSTRACT

Wheeled chairs, currently the only available solution to the mobility problem of those unable to walk, do not facilitate participation in the

range of activities associated with an independent and healthful existence. A legged mobility device, LEGS (Legged Electromechanical Multiple-Gaited Superchair), is currently under development at the University of Illinois at Chicago and the VA Hines Rehabilitation Research and Development Center. The LEGS design incorporates computer-controlled pantographic legs with capabilities that far exceed those of traditional wheelchairs. The recent progress in the area of robotics and the miniaturization of microprocessors is enabling the realization of this project.

INTRODUCTION

The liberation movement of the 1960s focused attention on the equal opportunity needs of various disenfranchised minorities. For disabled persons, equal opportunity needs focused on accessibility and independent mobility. The most obvious needs of employment and education have now, in part, been addressed by legislation governing accessible construction and transportation. But other opportunities of less obvious nature have remained neglected and inaccessible.

Tasks essential to independent and healthy life are identified by Mayer Spivak in "Design for Independent Living" (1). They represent not only our physiological needs, but psychological and spiritual needs as well. Maintaining our physical selves--eating, sleeping, excreting--assumes a mobility not available to all persons. The opportunity to meet with others, to mate, even to compete, is also dependent on the ability to move around independently. To produce, to create, to recreate--each of these affects our mental health, and all depend to some degree on mobility. For non-disabled persons, these environmental behaviors are small matters easily taken for granted. In short, there is not an aspect of our existence which is not affected by our ability to move around independently.

Advances in wheelchair design have provided increased ease and range of mobility, but they have not significantly reduced the limitations inherent to the use of wheels. The LEGS concept is predicated on the desire to expand the capabilities of mobility devices. Opportunities for independent and healthy living beyond the capacity of traditional wheelchairs have served as guidelines for the development of this project.

THE NEED

The world with which wheelchair users interface is largely defined by the capabilities of the wheelchair. Both natural and man-made environments present obstacles to people with mobile disability, but it is the latter which most effectively restricts their range of movement and activities. The natural environment has a variety of terrains, most of which are uneven and many of which are loose-surfaced, such as sand, rocks, and snow. None of these are easily traversed by the traditional wheelchair. Mayor Spivak's essential task of "Play" is usually associated with terrains like these (1). Recreational activities such as camping, hiking and outdoor sports put unusual demands on conventional wheelchairs. In fact only approximately 50% of the Earth's surface is accessible by wheeled or tracked vehicles (21). Perhaps rural dwellers and workers are more aware of this than people in the city where surfaces are paved or prepared for wheels in some way.

However, for urban wheelchair users, environmental features such as curbs, stairs, narrow passageways and doorways, cramped toilet facilities, escalators, and abrupt corners pose significant problems. Although most public urban environments must be and rightfully should be wheelchair accessible, private and residential environments are not likely to become accessible unless prompted by personal need. People using wheelchairs can and do adapt their own environments but for much of the population, however illadvised (1), stairs are the most space efficient, cost effective way to move from floor to floor.

These facts impact the independent living task of establishing territory and controlling space (1). To control space one must first get to it, become familiar with it and leave at will. Of course stairs prevent access to many spaces and they cannot be considered part of one's territory, but even when a person and their wheelchair are carried into a space, that person is then dependent on others to carry him out. This inability to leave at will or lack of independence will eliminate this space form one's territory.

Territory is also a major factor in social interactions. Those who control territory often control relationships. For meetings, whether personal or business, to function well there must be a sense of equality, a social reciprocity (1).

There are other aspects of the man-made world which limit accessibility as well. Because the seated position imposes limits on vertical and lateral movements, reaching high places such as cabinets and shelves is usually out of the question. Additionally, equipment designed to be operated by standing people cannot be used by seated persons. The lack of vertical mobility creates other problems for wheelchair users. Transferring in and out of a wheelchair can be a challenge since transfers are usually made to other furniture whose height can vary. Tremendous effort is required to lift oneself to a higher surface if the height of the wheelchair cannot vary. The social sphere is also affected by the lack of vertical movement. A wheelchair user is often looked down upon, both physically and psychologically, by non-disabled persons when first meeting. The stigma of imperfection is enhanced when social interaction is not at eye level (2, 3). Being restricted to a seated position for most of a day also poses health problems. Complications such as pressure sores, urinary infections, poor blood circulation, contractures, osteoporosis, spacticity, and calcium deposits are common medical problems among wheelchair users (2,5).

The capabilities of wheelchairs largely define the world with which their users interact. Rural or urban, indoors or outdoors, our environments impose a wide variety of restrictions on mobility and independent and healthful living. Wheelchairs do facilitate movement otherwise not possible for many people with disability, but there remains limits to accessibility and self-determination that the traditional wheelchair cannot address

TRADITIONAL SOLUTION

The wheelchair has been the traditional solution to mobility problems. Unfortunately, its design has changed little over the years. It was not until 1933 that a folding wheelchair was introduced (35). This innovation allowed for portability, and consequently expanded range. It was not until the early 1970s that innovation was improved upon when powered wheelchairs became commercially available. People unable to propel themselves in a manual wheelchair were freed of the passive role of being pushed by a non-disabled person, and as a result are now able to enjoy an unprecedented level of independence.

More recent widespread, but less significant, developments include the use of lighter frame materials, and size reductions. Various components have been developed to provide more adjustability and movement efficacy, thus resulting in more adjustable and lightweight manual chairs, especially sports chairs (6). In the area of power chairs there is a trend towards modular powered chassis designs (31) both four and three-wheeled. When the seat is designed as an independent part of a wheelchair, the chassis becomes a power base which can be customized, and upon which customized seats can be mounted. This modular approach to wheelchair design is better able to fulfill users' needs. All of these developments offer improvements over previous designs, yet they do not significantly extend the limits of accessibility and independence.

There have been numerous attempts to further increase the capabilities of wheeled mobility systems. In 1960, prompted by a competition sponsored by the Inventors Council and the President's Committee on the Employment of the Handicapped, 500 designers proposed manual and electric systems which would climb stairs as well as operate as conventional wheelchairs. Proposed solutions involved wheel clusters (a triad of wheels which rotate around a common center as well as on their own centers), tracks (similar to tank treads), and combinations of both. The winning solution--not awarded until 1962--used motor-driven tracks to climb stairs, and wheels when on level ground (7). (Various tracked chairs have since been introduced but none is currently on the market.(8,9)) In each case the designs, with their large lugged treads, are an abrasive solution in indoor environments. The tracked feature that allows the system to climb stairs prevents it from turning without disturbing the surface climbed on (8). Carpeted stairs and stairs that turn present real problems. Some systems are designed to only use treads for stair climbing, not for obstacles found in outdoor environments (9).

Another problem which has been addressed with design innovation is maneuverability. All regular wheelchair users have probably found themselves in a tight situation where they wanted to move sideways. An omni-directional wheelchair has been developed to solve this dilemma. This three-wheeled chair uses a wheel design consisting of a number of rollers, each mounted on an axis perpendicular to that of the wheel. No two wheels are parallel to each other, but are mounted in a triangular orientation. By powering different combinations of the three wheels, the chair can move in any direction without rotating the chair body (10).

Curb negotiation is possible with other designs. A powered wheelchair, produced in Britain, is able to negotiate curbs up to 130 mm in height with the use of a rocking arm which engages the curb and lifts the front wheels up (11). This design, like the one incorporating a raised fifth wheel, centrally positioned slightly in front of the two front wheels (12), are fine in an urban environment. But stairs and rough terrain are still barriers.

In general, powered chairs designed for outdoor mobility compromise indoor maneuverability. In order to handle rough terrain, the wheels are larger in diameter and in footprint for improved obstacle crossing and surface flotation. The frame is higher for ground clearance and the wheel base is increased for stability. These chairs are special purpose and secondary to the common wheelchair because of their impassibility through doorways and inability to turn around without moving furniture.

Other wheelchair developments which address medical, psychological and psychosocial problems include wheelchairs that aid the user in standing. Developed as early as 1972 (13, 14, 15), these wheelchairs provide a wide variety of benefits because of a change in posture; for example, improved blood circulation, muscle vitality, abdominal function, and reduced calcium rejection (2). Additionally, communication is improved both psychologically and socially when a person can see eye to eye. Standing also expands one's workspace. By allowing one to reach high places and to operate equipment intended for non-disabled people, vocational opportunities are improved as well. Daily living tasks and recreational activities are also facilitated (2).

Several standing wheelchairs are now on the market but most are manually propelled. The Naval Electronics Laboratory Center has developed a joystick-controlled, powered stand-up wheelchair (18), but its profile (about twice the size of normal powered chairs) excludes it from being a practical solution.

Another development is powered chairs which allow vertical movement, though not by adjusting the user's position into a standing posture but by the incorporation of a seat lift. The seat lift enables the user to raise and lower the seat height to reach high places and to match their height to tables or seated individuals in various settings such as the home, classrooms, theaters, or other public places. This feature also facilitates transfers by allowing movement from high to low, allowing gravity to assist. Ideally, a wheelchair seat should lower to the floor, allowing one to reach things on low shelves, in low cabinets, or on the floor. It would also allow one to play with small children and to work on cars, on plumbing, and in gardens. Wheelchairs have been designed with these capabilities, but were primarily intended for children or for special purpose applications (19, 20).

WALKING MACHINES

The marketplace has a myriad of mobility devices, all of which rely on wheels, and none of which solve all the problems outlined above. For many of these chairs, the benefit gained by their special feature is compromised by one or more of the following: lack of generality, reliability, increased cost, weight or size.

A radical departure from the wheeled mobility of a wheelchair is the legged locomotion of a walking machine. Functional walking machines have been developed as early as 20 years ago (21), but not until the advent of the microprocessor have real gains been made. Six-legged robots and vehicles with on-board computers have recently been built that travel where wheels or tracks cannot.

At Ohio State University, researchers have developed a six-legged transport vehicle for the U.S. Army. This hexapod, called the Adaptive Suspension Vehicle (ASV), is designed to carry a passenger/operator and cargo over terrain impassable by a tracked tank. Weighing over three tons and nearly measuring 20 ft. long, the ASV does not lend itself to adaptation for indoor environments (22).

Odetics, Inc., Anaheim, CA, has created what they call the first "functionoid." This six-legged hexapod, named Odex I, can climb stairs, go through doorways, achieve various profiles and traverse uneven terrain. Designed to work in hazardous environments such as mines and nuclear power plants, this remote control robot travels without a passenger (23).

Although most designs for walking machines have been six-legged hexapods, four is the minimum number of legs for smooth and stable operation, since at least three legs must remain on the ground at all times. Researchers at the Tokyo Institute of Technology have built a quadruped which climbs stairs without human intervention (24). Four-, three-, two-, and even one-legged hopping machines have also been built (24, 26). Their violent motion, however, prevents them from being considered for use with a passenger/ operator. A quadruped is the most practical means of operation for a walking chair to be maneuvered in tight places.

The walking machine principle can be applied to a walking wheelchair design, solving the disadvantages inherent in wheeled chairs. Whereas, wheels and tracks must roll over obstacles, legs can step over them. Vertical movement is inherently possible with legged designs by extending or retracting the legs. The walking machine body is decoupled from the surface it travels on. This forms an active suspension allowing for smoother, faster and more efficient movement on rough terrain (21).

To determine the usefulness of this principle as a means for mobility for persons with disability, as feasibility study is being conducted at the VA Hines Rehabilitation Research and Development Center and the University of Illinois at Chicago.

GOALS

LEGS will be a general purpose mobility aid, serving its user in daily living tasks both indoor and outdoor. It will not only travel where conventional powered wheelchairs travel, but also where they cannot. LEGS addresses most of the limitations of conventional chairs outlined above, by combining the features of many of the special-purpose chair models. In designing LEGS to be the sole means by which a person with mobile disability will meet these tasks, it will have a profound effect on daily life; its comprehensive list of capabilities eliminates the need to transfer to any other mobility device. This fact is obviously the most important of the many factors in "wheelchair availability - the probability that a wheelchair will be available (operational) to perform its tasks at a given instant in time" (32). Special purpose mobility devices do not allow for spontaneous use if one is not already in them. Initial capabilities of LEGS have been established as design criteria. These capabilities were determined by reviewing the literature and wheelchair standards (31,29) and assessing requirements for the fulfillment of a range of tasks integral to independent living (1). Architectural building data was analyzed, including furniture and public facilities for both typical and accessible conditions. Persons with disabilities were informally consulted for values and needs -- an indispensable part of the process and will be used throughout the design process. In addition to using potential users as resources in the design process, computers have proven invaluable. From the design of the pantograph leg to the development of gait algorithms, from the modeling of the seat to design visualization through animation, the computer has been an integral part of the design process. The three-dimensional computer model of LEGS shows interference of mechanical parts, range of motion for the legs, gait patterns in relation to a particular terrain and appearance for aesthetic considerations. As the project progresses, real-time computer simulations will be used in a "flight simulator" mode to develop gait and control algorithms.

The walking chair should enable the user to:

1. Walk up and down stairs with dimensions within the range of:
   riser: 4-8 in.
   tread: 8-15 in.
   riser to tread ratio: 0-85%
2. Walk up and down a 85% (37 degrees) grade.
3. Cross terrain with roughness of 10 in. in variation.
4. Perform forward and lateral body transfers.
5. Change posture from sitting to standing.
6. Adjust the seat from 15-26 in. from the floor.
7. Travel 10-20 miles per battery charge, depending on how many stair climbing cycles are performed (minimum of two stair climbing cycles).
8. Travel at a maximum speed of six mph on hard level surface

The design specifications for the walking chair are as follows:

1. Dimensions should not exceed:
   maximum width: 25 in.
   maximum length: 40 in.
2. Curb weight should be no greater than 250 lbs, capable of carrying a payload (person and cargo) of 250 lbs, with a total gross weight of 500 lbs.

The walking chair is expected to:

1. Cost between $10,000 - $20,000.
2. Operate for five years without major repair.
3. Be easily maintained.

All of these goals, with the exception of the minimum seat height requirement and maximum speed, are likely to be achievable based on current technology. Minimum seat height, at this time, will be 18 in. and maximum speed will be limited to three mph. Further research should enable us to achieve these goals.

MECHANICAL DESCRIPTION

LEGS is a quadruped walking chair based on the pantograph mechanism (Fig. 1). Chosen for its simplicity and efficiency, the four-bar linkage, or parallelogram, has three degrees of freedom (22): foot up/down, foot forward/backward, and leg rotation. This mechanism is similar to that of a tracing machine or a common articulated (Luxor) lamp. Each degree of freedom is driven by an electric motor through a ball screw. By controlling the three motors' speed and the time that they are on, many different foot placements and motions are possible. Locomotion is achieved when movement of all four legs is coordinated by the computer.

The leg design has been evolving since the project's inception. Initially, leg rotation was modeled after mammalian locomotion--as that of a horse. As the model turned, the legs pivoted laterally on a horizontal axis. Another aspect of this model was the maintained level of the chassis while climbing stairs (Fig. 2a). To accomplish this, the legs needed a large workspace and consequently they were made long. In order to meet the height specifications, the legs were mounted on each side of the chair (Fig. 3a).

Although this model had excellent obstacle crossing capabilities and the potential for wide variability in seat height, lateral transfers of the user to another chair or bed would be restricted by the presence of the legs at each side. In addition, the leg mechanisms considerably increased the width so that LEGS would have been unable to pass through many doorways. These compromises were deemed unacceptable, thus prompting development of another model.

The four legs are mounted beneath the chair and LEGS thus is no wider than the seat itself (Fig. 3b). This solved two problems: restricted passage due to width, and obstructed lateral transfers. In addition to these advantages, repositioning the legs under the chassis allows LEGS to benefit from a power base design. However, these changes required that the legs be shorter, and this created some problems. Shorter legs mean smaller workspaces. By redesigning the means by which the legs rotate, workspace was increased. The present leg design still uses the pantographic model to achieve the first two degrees of freedom, and these are adequate for straight-leg walks. However, when turning, the third degree of freedom (leg rotation) is achieved by pivoting around a vertical axis, instead of a horizontal axis (22) -- much like the rotation of spiders.

The shorter legs created problems for climbing stairs, also. The chassis could no longer be maintained level because of the smaller workspaces (Fig. 2b). To keep the user level and centered over the legs, a seat mechanism was designed and incorporated into LEGS (Fig. 4a). This device allows the seat to tilt at a angle corresponding to the chassis, and to move forward or backward properly locating the center of gravity (Fig. 4b).

This version of LEGS has the capability of assuming a wider stance, which provides increased stability. This feature would be valuable when climbing a steep incline, for example. In both models, the adjustability of the legs allows the user to tilt the chassis forward, by raising the rear and lowering the front. With the current model, though, this quality can be used in conjunction with the tilting seat mechanism, and with an adjustment to the back rest, allowing the user to achieve a standing posture of 85 degrees (Fig. 5). This feature enables the user to enjoy the psychological and physiological benefits of an upright position.

There are clear-cut advantages to the present model, but there are also some drawbacks when compared to the longer-legged version. It is expected that because of the increased leg length of the first model, its variable height capability would exceed that of the second model. It is also expected that its leg length would improve speed--both stair-climbing and walking--as well as performance on rough terrain, since the vertical stroke is increased. It is hoped that with further research it will be possible to integrate the capabilities of each design without compromise.

Just as legged mammals and insects have particular gaits for different terrain and activities, so must a walking machine. One of the responsibilities of LEGS' microprocessors will be control of particular gaits. A variety of gaits will be programmed to accommodate different needs -- from the relatively simple gait that smooth, level surfaces require, to those of more complexity, such as climbing stairs, or walking while rotating and changing height. Balance, as well as terrain, affects gait. Four-legged animals, when walking slowly, use a static balance system to avoid falling over. This involves keeping their center of gravity (mass) inside the area formed by the supporting feet. LEGS will balance in a similar way, preventing leg motion that would lead to unstable stances. To ensure stability, LEGS will also need to sense when a leg has a secure footing before proceeding--whatever the gait or surface. This will be accomplished with a sensor mounted on each leg to detect pressures passed through the foot. For a machine, this requires considerable computing power. The demands on the electronics are compounded by the need to minimize risk and to ensure reliability and performance.

For LEGS users, the range of traversable territory will expand considerably. When stairs are not an impediment, new employment opportunities become available, as well as different kinds of social involvement and recreational activities. As these become integrated into the user's life, dependency on LEGS will increase significantly; therefore, safety, reliability and availability are essential. To be an effective general-use mobility aid, it is imperative that LEGS not only have fail-safe controls to avoid unstable stances, inadvertent start-ups, and electronic failure (33), but that it also withstand environmental elements such as rain, snow, dirt, heat, cold, and electrical interference. Though not all of the guidelines established to guarantee wheelchair standards are directly applicable to the LEGS design , LEGS will be tested to determine compliance where appropriate (29).

OPERATION

Though mechanically and electronically sophisticated, the human interface with LEGS will be simple and intuitive. While an on-board computer will coordinate stable leg movement and foot placement, a joystick will control speed and direction of travel. Rotation, gait, and other modes of operation will be controlled by switches or in combination with another joystick. These controls will be interchangeable with other types, such as sip and puff or voice input, dependent upon the disability.

Because LEGS utilizes a powered chassis design, seat interchangeability and unobstructed transfers are features. A seat with adjustable foot supports, arm rests, and the ability to recline will be standard, but removable, allowing for special seating requirements of the user. Customizing options, such as the inclusion of leg, head and trunk supports have been accommodated in the flexibility of the design.

Seat height will adjust from 18 to 26 in. from the ground by means of LEGS' leg extension. Height variability aids transfer, increases visibility, and increases workspace. The ability to match one's height to co-workers' height has psychological benefits as well. In the second model of leg design, the change of height by leg extension also provides a variable profile. When in crowded or confined environment, a tall and narrow profile can be assumed. When there is a need for increased stability; for example, walking on a steep incline, a low, wide profile will be used. As mentioned in the discussion of leg designs, leg manipulation can be coordinated with use of the seat mechanism, and an adjustment to the back support, to achieve a standing posture.

This chair will carry a person on residential and commercial stairs while the user remains level at all times. Negotiating curbs and stairs then becomes merely a matter of stepping up or down. Omni-directional travel will be accomplished by stepping in the desired direction of travel. Consequently, tight spots which were formerly inaccessible will now be negotiable.

LEGS will be at home outdoors, as well. Walking on uneven or soft surfaces such as deep snow, loose sand, gravel are tasks well suited to a legged chair. Rough terrain up to 10 in. in variation will be negotiable. The active leg suspension will decouple the terrain variation from the user allowing a smoother ride and increased speed and efficiency in comparison to wheels (21). LEGS will have interchangeable shoes, necessary to accommodate various surface densities. Travelling on sand, for example, will require a wide footprint.

Under normal use, LEGS is expected to operate for five years without major repairs. Positioning of the battery and modular electronics in accessible locations will allow for easy general maintenance (31,33).

LEGS must be made affordable to those who need it, but realistically the cost of such a sophisticated device is dependent on state-of-the-art technology. The technology involved includes lightweight/high-strength materials such as carbon graphite or titanium, lightweight/high-powered motors such as rare-earth permanent-magnet types, lightweight/high-efficiency sealed batteries and high-speed distributed microprocessor-based electronics. As technology costs decrease, the price of LEGS should also decrease. The predicted price range of LEGS is approximately $10,000 - $20,000. This is reasonable in comparison to less capable stair-climbing chairs which are also in this price range.

AESTHETICS

Other aspects of concern regarding LEGS are its aesthetics and acceptability. New technology, in general, is received with skepticism. When cars first appeared on the roads, there was a considerable amount of finger-pointing, staring, and jeering. Historically, disabled persons have been subject to a similar level of reception -- even without being the operator of a walking machine. People with disability have had to compromise conformity and privacy to get to where they are today. This bold spirit was needed to overcome the paternalistic attitudes with which society regarded disabled people. This same spirit is bringing change to the traditional means of mobility and will be needed to usher in the application of robotics technologies to independent living.

Traditional designs for people with disability have been cumbersome and looked institutional. They cause a feelings of imperfection in the user, drawing attention to one's disability rather than one's ability. This stigmatizes and isolates people. The device itself can create a psychological barrier preventing social interaction (1,34). These designs look institutional because that is where they where designed and used. Designed by and for care givers, not the person with disability, some designs forced one to be dependent on others.

Now people with disability no longer have to live in institutions. They are becoming integrated into society and demanding their civil rights. This self-determination is visible in products designed for and by disabled people. Functional independence is the goal and aesthetics are of utmost importance (31,35). Medical professionals and rehabilitation engineers are now collaborating with industrial designers and disabled people to produce products that are unobtrusive, do not bring attention to their function but rather enhance the image of the user in a positive way.

Perhaps the biggest boost to the aesthetics of wheelchair design came from the sports wheelchair. Prompted by a change in regulations governing wheelchair sports after 1975, innovative design was driven by competition. Its economy of design, purity of form and sporty look appealed to even non-athletic users, producing the positive image of an active user (35). The use of color and new materials has further separated these designs from the institutional.

In designing LEGS' appearance, an effort is being made to maximize receptivity. This is a priority since wheelchair users often see their chairs as extensions of themselves, a tool that extends their abilities. Seeing a person using a chair with wheels to move around is becoming less unusual to the public now that more wheelchair users are active members of society. Seeing a person using a chair with legs that move will undoubtedly be unusual. Walking machines are not common place in any application. However the fact that people now commonly use mobility devices will certainly make the introduction of a new mobility device easier.

It is hoped that any reservations about the appearance will be dispelled by LEGS' wide range of capabilities. Just as using a sports wheelchair implies an active user perhaps using a walking chair would also for those who cannot propell themselves.

POTENTIAL

The nature of a legged machine leads to some exciting possibilities that are worthy of study. For example, the four legs of LEGS can be thought of as three-axis robot arms capable of remote manipulation. Given independent control of each leg, not only could objects be stepped over, they could be kicked or gently pushed to one side. These legs, with proper extensions, have the potential to be used for tasks as simple as scratching an itch (a major task for a person with quadriplegia) to the strong-armed task of lifting the user and assisting in transfers. In the latter case it would be necessary to lower LEGS on to its own base to free up two or more legs and to maintain stability. In the areas of recreation and competition the terms "wheelchair sports" and "wheelchair dancing" will take on a new meaning when a legged chair becomes available to disabled people.

CONCLUSION

Most people live, work, and play in environments which are not easily accessible to those with mobile disability. Whether indoors or outdoors, obstacles exist that wheelchairs cannot easily negotiate. Some man-made, some natural. Regardless of origin, their impact on disabled persons extends beyond the issue of mobility. Wheels do improve mobility, but the traditional wheelchair does not significantly enable a self-determined and independent lifestyle. Recent advances in the field of robotics, the miniaturization of microprocessors, as well as the technological advances in high-strength, low-weight materials make the development of LEGS realistic. This new mobility device may assist disabled persons with movement throughout man-made and natural environments. But it is hoped LEGS will facilitate much more than this. The ideas of accessibility and independent mobility continue to remain in focus as requirements for equal opportunity. While the most obvious needs of accessible construction and transportation are being addressed, other opportunities of less obvious nature remain neglected and inaccessible. Activities which allow self-determination and enrichment cannot be excluded from the concept of accessibility rights. It is this broader interpretation of what accessibility means has guided the development of the LEGS design.

It is hoped LEGS' versatility will translate this concept into reality for those with mobile disability.

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