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ADJUSTMENT OF THE HAND THROTTLE OF A MOBILITY SCOOTER FOR ELDERLY PEOPLE

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ABSTRACT

In the last years assistive technologies to preserve elderly people a self determined and independent life receive growing attention. Mobility is one of the biggest issues for a self-determined life, in particular for elderly people. Social participation and daily activities like shopping, errands or doctor visits require mobility. Therefore mobility is a prerequisite to maintain autonomy and self-determination in old age. Mobility scooter are able to preserve the mobility of elderly people, but it is very challenging to control such a vehicle, especially for elderly people. Therefore this paper presents some drive assistance function to support the operator and increase the safety. Three different functions to improve the security and decrease the challenging control will be introduced: a hand throttle regulation, a drive off function and an emergency stop. Some of these functions were validated and tested by several elderly people to find the best configuration.

Index Terms— mobility scooter, drive assistance system, mobile robot, emergency stop, throttle regulation, TIDE

1. INTRODUCTION

In Germany the portion of people aged over 65 years will increase from 16% up to more than 25% in the next 20 years [1]. Normal aging processes are associated with cognitive and physical losses. Any loss or decline of capabilities threaten the mobility of elderly people and therefore the individual's self-determined everyday life. Mobility is one of the biggest issues for an independent and self-determined life, in particular for elderly people. Social participation and daily activities like shopping, errands or doctor visits require mobility. Therefore mobility is a prerequisite to maintain autonomy and self-determination in old age.

In the research association FitForAge of the Bavarian Research Foundation a team of scientists and engineers of 13 chairs of the four Bavarian Universities Erlangen-Nuremberg, Munich, Regensburg and Würzburg with 25 industrial partners is cooperating to develop products and services for an aging society. The aim of the research association is the development of technology-based solutions for aging people in their future life, to assist them at home, in their professional life, in the communication with their surroundings and in their participating of road traffic. Finally, not only elderly people should profit from this solutions, but all groups of society.

A part of the Fit4Age project [2] is the development of a mobility scooter to support the mobility of elderly people. The mobility scooter is equipped with drive assistance functions, like obstacle avoidance, to relieve the operator from the challenging control of the vehicle. Furthermore autonomous functions, like human following, and a navigation system, adapted to the requirement of the mobility scooter will be integrated.

The objectives of this paper are some of the drive assistance functions: the adjustment of the hand throttle, a drive off function, and an emergency stop. The regulation of the hand throttle enables a configuration of the scooter acceleration and velocity. Thus both parameters can be adapted to the operator and his capabilities. The drive off function adjusts the drive off configuration of the mobility scooter. The emergency stop halts the mobility scooter in cases of too fast acceleration e.g. triggered by shocks or spasms. Some of these function were evaluated and tested by elderly people.

In the recent years several wheelchairs were developed to support elderly people in buildings [3, 4, 5, 6, 7]. These wheelchairs are mostly equipped with autonomous navigation [3, 5, 6] and/or obstacle avoidance functions [8, 4, 6, 7]. Furthermore some of these wheelchairs can be used as service robot or in rehabilitation application [9, 10]. Even some special control extensions enable disable people to control wheelchairs [11, 12, 13]. In [14] an emergency functions was introduced. This function monitors all driving commands of the operator and in case of too fast changes of the commands or too much pressure on the joystick the wheelchair was stopped. But all this functions are designed for indoor applications like [15]. Hence to ensure a reliable use in an urban environment a mobility scooter is used in this project. In [16] a competency test was conducted in order to define the basic skills required to drive the mobility scooter safely. More than 65% of the participants failed at least one test item. For this reason the three drive assistance functions were developed and implemented on the mobility scooter.

The publication is organized as follows: The next chapter introduces the mobility scooter and all modifications of the vehicle. In section III the three drive assistance system function are explained. Afterwards the evaluation of test-runs follows. Finally the last chapter summarizes and points out the future work.

Fig. 1. The basic mobility scooter

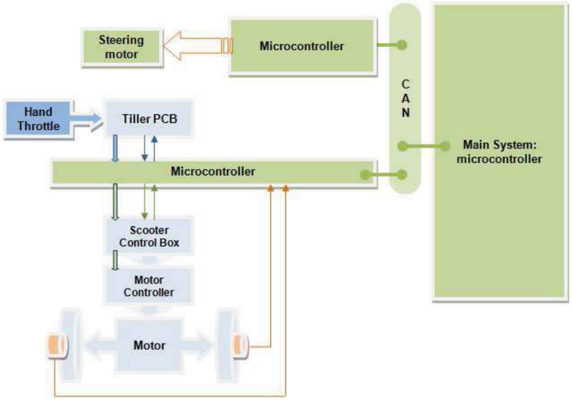

Fig. 2. Overview of the mobility scooter electronics

2. THE MOBILITY SCOOTER

The car-like mobility scooter Trophy 4W manufactured by Handicare GmbH is used as basis (see Fig. 1). The vehicle satisfies the German MOT approval, hence it is permitted to drive on public streets. It can drive up to 15 km/h and can cover a distance up to 60km. Originally the rear axis is actuated by the electric motor and the steering is done by the operator manually. The basic on-board electronics consist of 3 main parts: a tiller printed circuit board (PCB), the scooter control box (SCB) and the motor controller (see Fig. 2). The tiller PCB offers all interfaces to the operator (lights, horn, velocity, break, status). All lights, the horn, the batteries, the motor controller as well as the tiller PCB are connected with the SCB. This box executes all commands from the operator and controls the complete mobility scooter.

The basic mobility scooter offers no control interface for a PC or a micro-controller. Therefore the connection between the tiller PCB and the SCB was wire-tapped using a micro-controller. Hence, it was possible to listen to all commands of the operator and the feedback of the SCB. This interface enables the control of all functionalities of the scooter and the commands of the operator can be overwritten in case of emergency. Moreover two incremental sensors, one at each rear wheel, are connected to this micro-controller. Using these sensors the velocity of the vehicle can be measured.

Using this micro-controller and the two incremental sensors, a closed loop velocity controller was designed. The characteristics of the motor and mobility scooter were determined and integrated to a simulation in Matlab. Several controller were simulated to find the best one for the vehicle. A closed loop PI controller achieved the best results in the simulations. Based on this results a PI controller was implemented on the micro-controller and extensively tested using the same parameters as in the simulation. Only some small modifications were needed to get a quite suitable velocity controller for the mobility scooter.

A steering motor was mounted on the steering link to enable autonomous driving. The steering motor can be controlled via a second micro-controller. A hall sensor, measuring the steering angle, and gyroscopes to determine the current rotational speed are connected to the second micro-controller as well. This micro-controller and the first one are used as slaves. They preprocess and transmit sensor data and receive commands from the master.

The high level functions and algorithms are implemented on a third more powerful micro-controller. This micro-controller act as master on the mobility scooter. All micro-controllers are connected via a CAN bus. The master micro-controller offers a lot of additional interfaces for further sensors like GPS and US. A complete overview of the mobility scooter electronics is shown in Fig. 2

All following functions are implemented on the first micro-controller and they can be activated and configured via the master. Using this micro-controller the functions are able to modify the commands of the operator without being noticed. Figure 3 shows the final mobility scooter equipped with all sensors.

3. DRIVE ASSISTANCE FUNCTIONS

The following section will introduce the three assistance functions: the new regulation of the hand throttle, the drive off function, and the emergency stop function. Furthermore the integration in the mobility scooter system is explained.

3.1. Hand throttle regulation

For elderly people it is a big challenge to control any kind of vehicle, caused by movement disability, cognition and visual attention [16]. Especially in narrow environments, the scooter must be controlled safely to avoid accidents. It is already challenging for younger

Fig. 3. The current mobiliy scooter equipped with electronics and sensors

people, because the velocity between 0 km/h and 15 km/h is originally ranged proportionally over the complete hand throttle. So it is very difficult to control the mobility scooter with low velocity. Already some small accidents happened in the robotics lab of the University of Würzburg, most frequently at door frames.

Therefore a new regulation of the hand throttle was implemented on the micro-controller, which is wire-trapping the connection between tille PCB and SCB. There it is possible to observe the hand throttle input of the operator and to generate new commands. The SCB is not able to notice the adaption and just executes the commands. Two new regulations of the hand throttle were implemented in this project. Fig. 4 shows the original regulation (ID0) and the two new regulations (ID1 + ID2).

The new regulation of the hand throttle was distributed in three steps. The maximum velocity of the first 30% of the hand throttle is limited to 2km/h (ID1) and 3km/h (ID2). Compared to more than 5 km/h in the origin (ID0) it is much slower. The next step of the new regulations is again much slower compared to ID0. In the last step the slope of ID1 and ID2 ist higher, to be able to drive up to 15 km/h. Due to the new regulations of the hand throttle it is easier to control the mobility scooter at low velocities. For sure it is more challenging to control the vehicle at high velocities. But it is only possible to drive high velocities if there is enough free space. In such a case it makes no difference if the velocity is 13km/h or 14km/h compared to narrow environment, where such a difference can cause an accident.

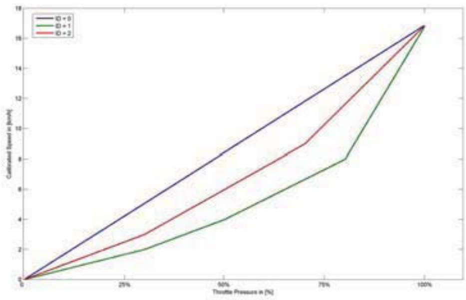

Fig. 4. The original (ID0) and the new (ID1, ID2) hand throttle regulations

3.2. Drive off

At several tests with elderly people it turned out that driving off the mobility scooter is a little bit tricky. The people push the hand throttle slightly to drive off the vehicle. And if the scooter is not starting immediately, they push the hand throttle more and more or completely. But sometimes there is a gab between the first drive command of the user and the start of the the motor especially after a long break or after the power-on of the scooter. This gab is caused by the controlling of the motor. After the power-on of the vehicle, the SCB does not know in which direction the operator wants to drive (forward or backward). The motor and the motor-controller are in a kind of "neutral" position. Only when the first driving command is generated the motor is configured to the corresponding direction. This switch needs some time, thus there is a gab between the first driving commands and the drive off of the mobility scooter. If the motor is set once and there is no big break anymore, the gab is really small. A experienced operator knows this behavior and can adjust himself to that issue. But for learners it is not so easy and often they react very nervous and hectic in such cases.

If there is a big gab between the first driving command and the drive off learner react in two different ways. On the one hand they push the hand throttle slightly more and more. Thus the scooter will drive off really fast and the operator is usually very surprised about the "kick-start". This often leads to hectic and unsafe driving situations. On the other hand the operator pushes the hand throttle completely. Because of the full throttle the mobility scooter assumes some error or failure and will not drive off the vehicle until the hand throttle is unhanded and pushed again.

To avoid both situations a drive off assistant function was implemented on the similar micro-controller like the hand throttle regulation. This function observes the driving commands of the operator. If the mobility scooter is not moving and a first driving commands are received, the drive off function initiates the drive off. The maximum velocity of the scooter is limited by this function according to the current state of the drive off process and the selected hand throttle configuration. Thus a "kick-start"' of the mobility scooter is not possible anymore. Furthermore if the operator pushes the hand throttle completely, the drive off function limits the velocity and the vehicle will slowly and safely drive off.

3.3. Emergency stop

The usage of the mobility scooter at the chair revealed that the operator not loses his hand of the hand-throttle in case of a shock. Rather the operator cramps and pushes the hand throttle the first seconds entirely. Thus the risk of an accident increases and already some accidents happened in different test phases. Hence an emergency stop function was integrated to avoid further accidents.

At a normal ride of the mobility scooter, two subsequent driving commands are close together. In cases of cramps or shocks the operator pushes the hand throttle much faster compared to normal behaviors. Whereby the gap between two subsequent commands is much bigger. The emergency stop function observes the operators velocity commands generated by the hand throttle every 30ms. If the gap between two subsequent values exceed a threshold, the mobility scooter were stopped. Various tests were conducted to find a quite suitable threshold. The emergency stop function was implemented on the same micro-controller like the other two functions.

4. EXPERIMENTS

After the description of the three drive assistance functions, a user evaluation follows. Elderly people were invited to evaluate the drive assistance functions at the University of Würzburg. Therefore a test course on the campus was designed.

The emergency function was not integrated to the tests, because shocks or cramps of the elderly people were not expected. But the function was integrated to the questionnaire at the end of the test.

4.1. Experiment setup

The experiment setup is geared to the driver competency tests in [16]. Several test items (like weave test, 180° turn, 90° turn,...) of the competency were taken over and included in the experiments.

Before the test persons started with the experiments the mobility scooter was introduced. Especially the mode of operation of the vehicle were explained and demonstrated in detail, because most of the test persons are not used to such kind of vehicles.

At the beginning the drive off function was evaluated. Three runs with different configurations were

Fig. 5. A test person on the mobility scooter

defined and were evaluated by the elderly people. At a slight slope the test persons should drive off the mobility scooter three times, one time for each configuration. At the first test run, the drive off function was deactivated, hence the mobility scooter accelerated like a basic one without all extensions (hand throttle regulations ID0 was selected). In the second run, the drive off function was activated. For this run the hand throttle ID0 was selected which is the basic mobility scooter configuration. In the last run, the drive off function was activated too, but the hand throttle ID1 was selected. As a criteria, the successful and unsuccessful drive offs of the mobility scooter were counted. The second criteria was the feedback of the test persons. After every test-run, they were asked about the handling of the vehicle and how safe they felt.

The second part of the experiments was a handling course consisting of a weave test (between small stones spaced 1.5m - 1.9m apart), a transposition maneuver, a 90ï¿½ right turn, a 180ï¿½ left turn and a narrow (3m long). For every item a boundary was marked on the floor. The test persons had to drive the course once with every kind of hand throttle regulation. The order of the hand throttle regulations was ID1, ID0 and in the final test-run ID2. As criteria, the needed time for every item and the complete time were measured. Additionally the failures were counted, for example leaving the path or piling a stone. Again the feedback of the test person were considered. After every test run, the elderly people were again asked some questions, too.

To avoid a learning process in the test-runs, every person was allowed to drive the course twice before starting. On that way the test persons were getting used to the course. For sure, there was still a learning process within the sequenced runs, but this can not be prevented. The biggest learning step was reached in these first two runs. Additionally the people knew the course and did not lose the path of the test-run which happened sometimes in the first or second practice run.

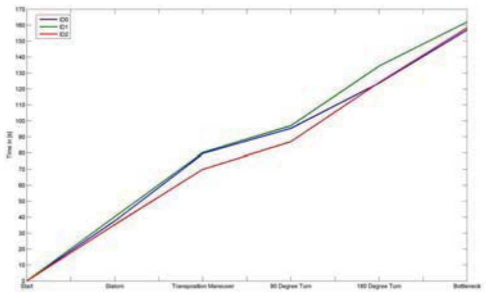

Fig. 6. The average total time of the test persons needed for the handling course.

4.2. Results

Several elderly people took part in the evaluation of the the drive off function and the hand throttle regulation. On Fig. 5 one of the test persons is riding the mobility scooter. The experiments have been carried out on a street next to robotics test area on the campus of the University of Würzburg.

In the first part of the experiments the drive off function was evaluated. Every time the drive off function was activated all persons were able to drive off the mobility scooter successfully. One of three persons was not able to drive off the scooter in the first run (drive off function deactivated). Additionally the questionnaire showed that the persons feel more safe when the function was activated. Surprisingly there were no big differences between the second and the third test-run regarding the feel of safety despite the varying hand throttle configuration. The people felt only a little bit more safe with ID1, but not really much. All of them preferred the configuration of the final run with activated drive off function and hand throttle regulation ID1. This result shows, that the drive off function helps people to feel more safe at the drive off. Additionally this function decreases the challenging operation of the vehicle, because the drive off worked every time well.

At first the results of the handling course are not really plausible like the results of the drive off function. There was no big difference between the three IDs regarded to the failure and the total time as shown in Fig. 6. Additionally the learning process of the test persons still affected the results. For example one of the test persons mentioned in the questionnaire, that he got more and more used to the course. Nevertheless, the test persons noticed the difference of the hand throttle regulation. Additionally the attendees were able to see differences at the driving behaviors of the test persons. If ID0 was selected the operator reacted in many cases very hectic and unsafe. The test person had to do a lot of small correction to keep the vehicle on the course compared to the safe and unstressed test-run with ID1 or ID2. It was obvious that the new regulation of the hand throttle supports the operator and decreases the challenging control of the mobility scooter. It is remarkable, that the average total time of all test runs is approximately the same, despite the varying hand throttle regulation.

At last the feedback of the test persons about the emergency stop function was very positively. All of the persons wanted such a function integrated in the mobility scooter.

5. CONCLUSION

In this paper three drive assistance systems were implemented on a mobility scooter to support the mobility of elderly people. The first assistance system was a new hand throttle regulation. This function allows a better control of the vehicle, especially at low velocities. A drive off function supports the operator to drive off the mobility scooter more safe and reliable. Therefore the drive off velocity was limited. Furthermore an emergency stop function was integrated on the vehicle. This function stops the vehicle, if the gab between two subsequent velocity driving commands is too big. Thereby a shock or cramp of the operator is assumed.

The new hand throttle regulation and the drive off function were evaluated by drive test-runs with elderly people. Therefore an experiment setup was established and introduced. Several elderly people took part at these experiments.

The experiments showed that the drive off function supports elderly people during the drive off process. If the function was activated the mobility scooter drove off successfully in every case. Additionally the test persons felt more safe. Furthermore the experiments showed that the new regulation of the hand throttle enables a control of the vehicle which is more safe and easier compared to the original regulation. Hence, all three assistance systems support the operator to decrease the challenging control of the mobility scooter successfully and increase the safety.

In future more detailed experiments must be done to verify the already gained results. A new experiment setup must be defined and the aspects of learning must be considered.

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