Evaluation of User Interface Performing a DVZ-Fuzzy Logic Pilot For Powered Wheelchair

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Abstract:

This paper presents the preliminary tests of an adapted user interface that performs an hybrid fuzzy-Deformable Virtual Zone(DVZ) pilot. The proposed concept uses a safely guidance algorithm for the powered wheelchair user and a laser range sensor to avoid collision. An adapted user interface is developed so that the accessibility and the mobility of disable or aged people especially those suffering from low cognitive abilities will be enhanced. Trials with the proposed algorithm detected obstacles and avoid them in 80% of trials with different objects and generated safe paths for the interface user.

Keywords: *Assistive control, user interface, DVZ Obstacle avoidance, fuzzy guidance, improving mobility, disable people.*

1. Introduction

Aiming to better the life quality of the older adults or the disable people, much focus must be upon the assistive technologies. The use of these technologies is became an important challenge because of the growing proportion of the disabilities : cognitive ability, sensory impairments and behavioral skills.

Older adults are generally excluded from assitive technologies that deals with the problems resulted from these impairments. This is due to the need of the older adults to some additional safely measures.

While people with disabilities have a great challenge to manipulate the variety of existing devices as they consider the differences of disabilities. Several alternative ways were used in order to finalize one task. For example adapted interfaces were used to compensate for motor dexterity.

In general, we can't design a unique assitive technique for the hole disable population as each one has her own solution that depends on the kind of disability : cognitive, sensory impairment or behavioral skills. We propose the following guidelines needed to concept an adapted user interface, basing on the research fields of human computer interaction [6], [4] and [15] :

- interface should communicate with multiple devices. Each one could compensate for a kind of disability.
- Interface should be simple to use : a short number of steps is needed especially for the person suffering from cognitive impairments.
- Interface should consider different forms of prompting that helps the user to realise a process.

The system presented in this paper is an adapted user interface for controlling robotic wheelchair. This interface is used to improve mobility of disable persons by applying intelligent technology. A DVZ-fuzzy logic pilot is developed to perform the user guidance past obstacles.

An study of related works to build these kinds of autonomous platforms for disable people will be presented. A description of the robotic system and the main programs used will be projected. The obtained results additionally to a detailed discussion will be presented. Finally, future research will be provided.

2. Background

During the last decades, many researches had been focused on tailoring the control system to the user of a robotic system. This research belonging to the field of artificial intelligence, aims to electrically-power a wheelchair so that it brings independence suffered by the mobility-impaired or older adults.

Traditionally, powered wheelchairs have been based on an intuitive solution (joystick). Nevertheless, different interaction methods shall be applied to ensure efficiency and safety. Preliminary researches are carried out basing on the Smart wheelchair [13], then researches [10] were investigating in the fields of face and gaze interface and hand-gesture recognition [7]. More novel fields are later being investigated to compensate the poor reactions of the joystick control. These range from those that used a high level of autonomy as Taha et al. [14] to the Millan et al. [12] brain machine interface offering a very low user input resolution. In these platforms, the actor usually supervises while the wheelchair is reaching the target. This kind of control method is suitable for users afflicted by hard physical disabilities.

There are further mixed control systems that swap between distinct mode of operations such as the "Navchair" robotic system [9], or the controller proposed by Carlson [3] that used a collaborative technique basing on secondary task experiments mobility : they keep the control user-initiated and only adapt signals where necessary. Unfortunately, this type of assistance requires a significant effort from the actor which is not suitable for people suffering from cognitive harm.

Other researchers [11] proposed both an anticollision and a prompting system that helps older adults guiding safely past obstacles. There are also works dealing with the accessibility of people with disabilities by developing four versions of flexible interfaces for assistive devices [15], [16]. These interfaces are based on input device and a camera.

In this paper, we suggest a mixed control system that switches from a guidance system to an anticollision pilot. An adapted user interface was developed so that the user accessibility is improved. The robotic wheelchair currently employs the underlying three operating modes :

- goal-seeking and path following of a unicycle mobile robot : navigator
- obstacle avoidance architecture using Laser sensor : reacting pilot
- the computation between the two objectives using a fuzzy switching
- an adapted user interface that shows different forms of prompting that helps the user to adapt the wheelchair control.

3. System Architecture

3.1. Overview of the System

The studied vehicle is a robotic wheelchair with two caster wheels and two independent driving wheels that provide the mobile base with two degrees of mobility [2]. We have mounted a Laptop upon our system and connected it to a joystick and motor control unit using a CB-405 bloc system as shown in Fig.1. This allows us to intercept joystick signals and alter them (where necessary), before sending them to the wheelchair s motor control unit (Fig.2). We have also developed a computer laser-based localization system that works in unknown indoor environments. In order to be aware of its surroundings, the wheelchair must know its relation to a coordinate system. Two encoders "Easy Roller ENC300CPR" are mounted on the chair's wheels to determine its location. These encoders provide 300 impulses per tour and output signals used to measure the linear and angular displacement of each wheel.

The studied system consists of a robot controlled via a serial communication from the PC. The terminal configuration for the host computer PC must be set to "9600 Bauds, 8 bit, 1 start bit, 2 stop bit and no parity". The laptop executes the task of calculating the optimized trajectory using the fuzzy logic controller, determining the robot relative position using odometer measurements and avoiding obstacles. The communication with the laser sensor is ensured via USB port, with a simple protocol to acquire data. [5]

3.2. Software Interface

The wheelchair command system running on the Laptop is operated through a 2D graphical user interface (GUI) presented in Fig.3 and Fig. 4. There are three operation modes in this interface : goal-seeking, path following and obstacle avoidance. The user can choose one or more running mode in the same test. First, the user can interactively place the start and the end points on the displayed environment. Second, he can place different obstacle modes (corridor, with/without corner situation). Third, he can also place "waypoints which are automatically interpolated using B-splines, to create a smooth path". These waypoints and obstacles are easily deleted or dragged around the environment at any time to amend the desired driving trajectory. The chair can then follow the given path or attempt the desired target by making use of the fuzzy logic control-

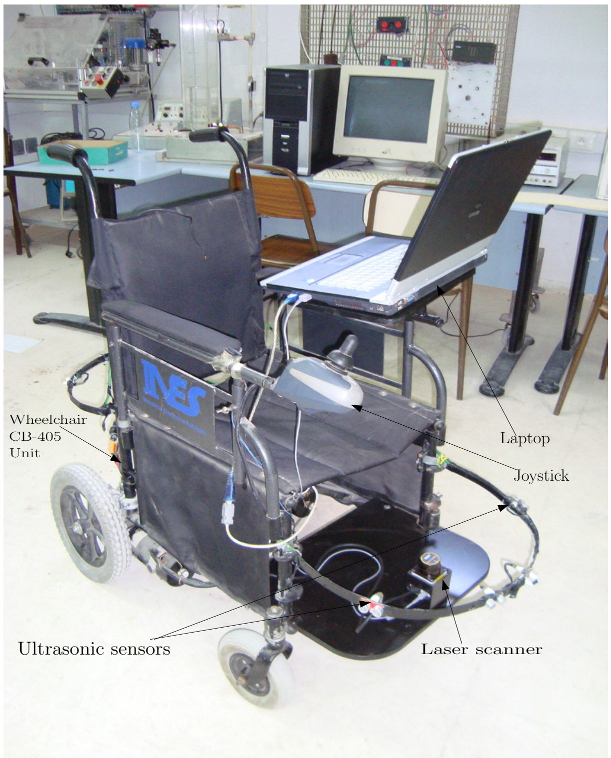

Fig. 1. "Current configuration of the wheelchair. The software on the Laptop uses the measures from the CB405 and the laser to control the wheelchair motion" [2].

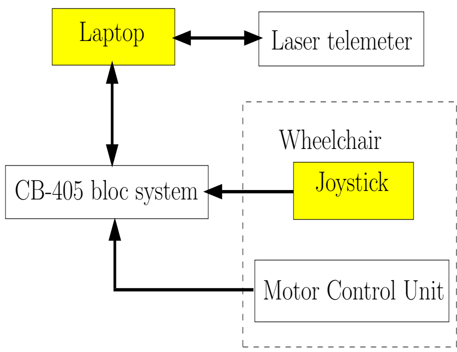

Fig. 2. "Diagram highlighting the user interaction methods : through the joystick or the Laptop. All the joystick commands are processed by the CB-405 module before being sent to the wheelchair motors" [2].

ler we have developed in previous works. It will be able also to avoid unknown obstacles basing on its reactive behaviours presented in Section III-C.

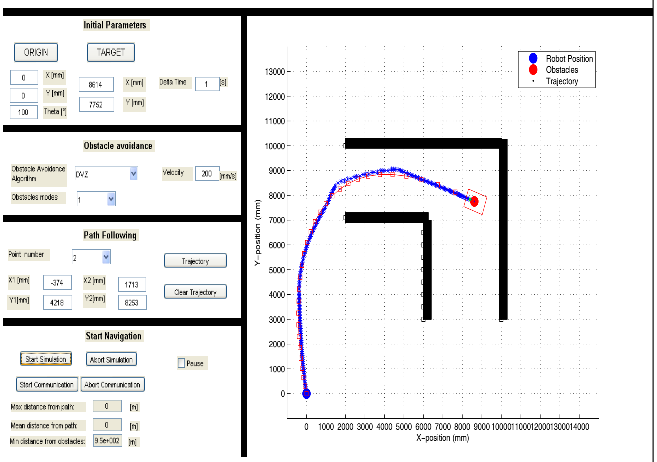

Fig. 3. The 2D-interface, displaying start and end points with 3 user-waypoints, which have been interpolated with B-splines. The obstacle mode chosen is a corridor with corner situation.

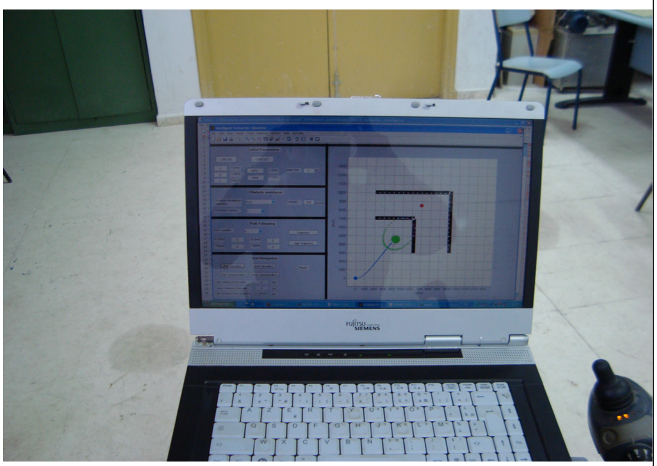

Fig. 4. The 2D-interface, displaying the wheelchair navigation.

3.3. Reactive Obstacle Avoidance Pilot

In our architecture the wheelchair must attempt a target or a suit of targets while avoiding obstacles assumed to be unknown. Consequently, we decided to use a reactive pilot based on the DVZ as described in [8]. This method is built using a virtual risk zone surrounding the robot which can be deformed due to the proximity information. The risk zone deformation is due to the proximity information. The system reaction drives the robot velocities (linear and angular velocities, V and ω) function of this deformation calculation. In general, the risk zone deformed by an obstacle can be reformed by reacting on the robot velocities. A laser sensor was then positioned looking directly in front of the chair. This sensor provides distances to the obstacles present in the robot's surrounding area with maximum four meters distance to the chair's center. For a more comprehensive review of the application of this method on the robotic wheelchair, refer to [1] and [2].

3.4. Fuzzy Switching

In this switching method we introduce the concept of safe mini-intrusion. This intrusion information generated with the DVZ controller provides a safe commutation from the current wheelchair position to a sub-goal in the case of corner situation as shown in Fig.5. This problem occurs when the deformed DVZ becomes symmetric with respect to the linear velocity direction. The reaction to this situation is to reduce the velocity, and to rotate until the obstacle is present in one side. In consequence, the speed will be reduced to zero or a negative value. To avoid this local minima problem [8], we have considered a left in front intrusion I_l calculated for $\theta \leq \alpha < \theta + 60^\circ$, a right in front one I_r calculated for $\theta - 60^\circ \leq \alpha < \theta$, a left side intrusion I_{ls} calculated for $\theta + 60^\circ \leq \alpha < \theta + \pi$ and a right side intrusion I_{rs} calculated for $\theta + \pi \leq \alpha < \theta - 60^\circ$ as presented in Fig.6.

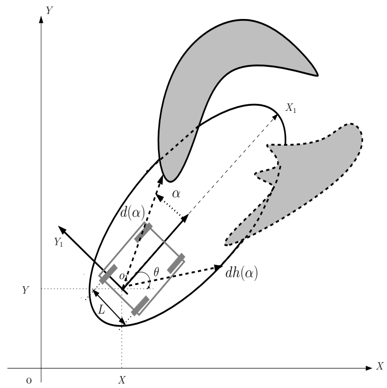

Fig. 5. The elliptic risk zone is surrounding the wheelchair. This risk zone is a function of d_h *and* α.The deformed risk zone is the product of two parts : the first is computed using the distance measured by the laser sensor to the obstacles, the second is basing only on distances inside the undeformed risk zone and noted $d(\alpha)$

The basic idea of this switch is the product of two parts. In the first one, obstacles are present in front of the wheelchair (I_l *or* I_r or both), so that it avoids them. In the second one, obstacles are present in one or two sides (I_{ls} *or* I_{rs} or both), the robot can attempt its targets without avoiding obstacles. To do so, we have developed a fuzzy switch [2].

3.5. Hypotheses

Experimental and simulation tests was designed to investigate the hypotheses about the adapted user interface. These hypotheses targets to judge the accessibility of laser-sensor as well as encoders inputs and the complexity of the steps needed to perform the user objective.

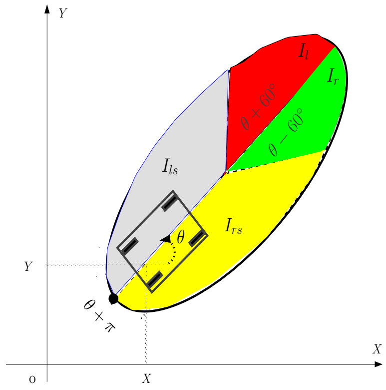

Fig. 6. This figure highlights the four safe mini-intrusion : I_l, I_r, I_{ls} and I_{rs}. Rules are designed for multiple scenario that can be helpful for the user.

Hypothesis 1: The proposed user interface is easy to use but needs some prompting levels. It accommodates several devices : encoders measures, laser sensor and ultrasonic proximity informations (guideline1). Furthermore, it has two step process for target selection (guideline2) and one step to start the guidance. However, the selection of the obstacle disposal is not adapted by the user.

Hypothesis 2: It should be more confident for the user to navigate in environment with obstacles present in one side than in two sides.

Hypothesis 3: The selection of waypoints and the generation of trajectory should perform the desired target safely and in few moment. One objective of this research is to understand which guidance controller works well for the user : totally autonomous navigation or partial navigation in which the user intercept by choosing the trajectory he wants to follow in order to achieve his target.

4. Experiment Methodology

Trials was run in Janvier 2012 to evaluate the effectiveness of the user interface used to control the wheelchair. The participants are student researchers.

4.1. Participants

The participants were invited to participate in the experiments. Four candidates accepted : they were students of the Engineering School of Sfax and aged between twenty and thirty two years old. All of them had a high cognitive ability, and were able to manipulate an interface (selection of points using the mouse). The candidates were two men and two women. The four participants were able to use the power wheelchair and the interface as an access method. Table 2 describes the participants' cognitive abilities, behavioral abilities, and interface operating.

Each participant was given an initial profile of a guidance problem to deal with. A profile contains steps for using the interface based. Different disposal of the obstacles in the envioronment surrounding the user were used : corridor, objects in one side and others in two sides.

4.2. Experiment Concept and Requirements

Four conditions were tested : corridor guidance and a totally autonomous wheelchair versus a trajectory choosed by the user, and guidance with obstacles in one side versus two sides.

Condition A: the user had an interface showing his surrounding environment with corridor situation as well as his initial position (Fig. 7 or Fig. 8). He was to move the mouse in order to select the target location that he wants to achieve and press a button in the interface to let the wheelchair starting the navigation autonomously.

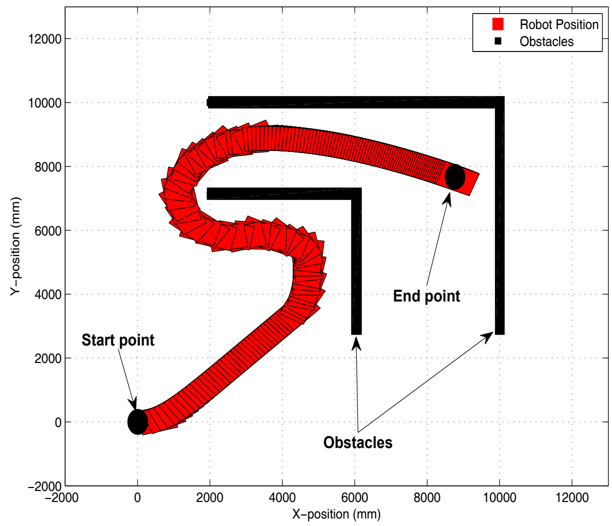

Fig. 7. Corridor navigation : the user select only the target point and initiated the navigation.

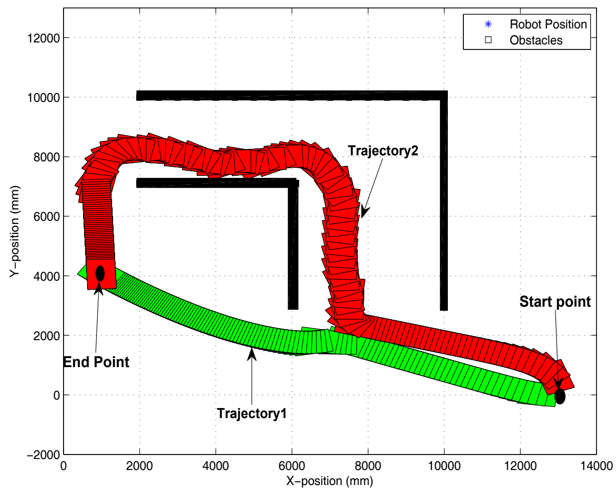

Fig. 8. Corridor navigation : different starting orientation.

Condition B the user had the same interface as that displayed in condition A (Fig. 9). The participant was to use the mouse to move the different points shown on the screen in order to generate his

Tab. 1. Candidate abilities

	Age	*Cognition*	*Behavior*	*Vision*	*Interface*
P1	20	*able to learn new skills*	*None*	*Functional*	*Standard*
P2	27	*standard*	*Sociable*	*Functional*	*Standard*
P3	32	*Good memory*	*Cooperative*	*Functional*	*Standard*
P4	25	*distractible*	*None*	*Functional*	*Standard*

own trajectory. Then he was to press a button to initiate the wheelchair to follow the designed path.

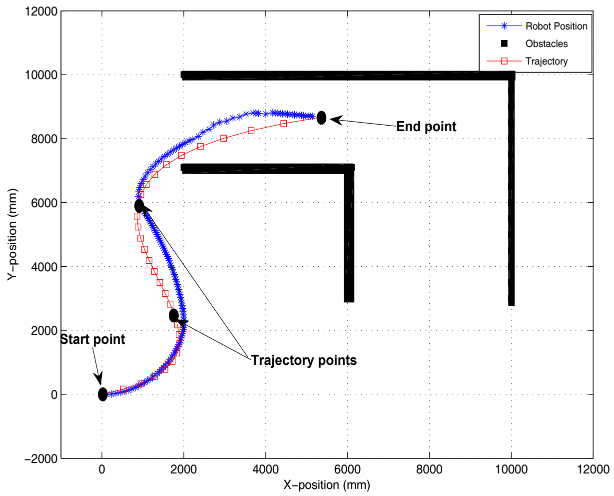

Fig. 9. Path following : series of waypoints points selected by the user.

Condition C The user had different objects disposed on one side in the environment and displayed on the interface screen (Fig. 10). Then he was to choose either a trajectory to follow either a target to reach.

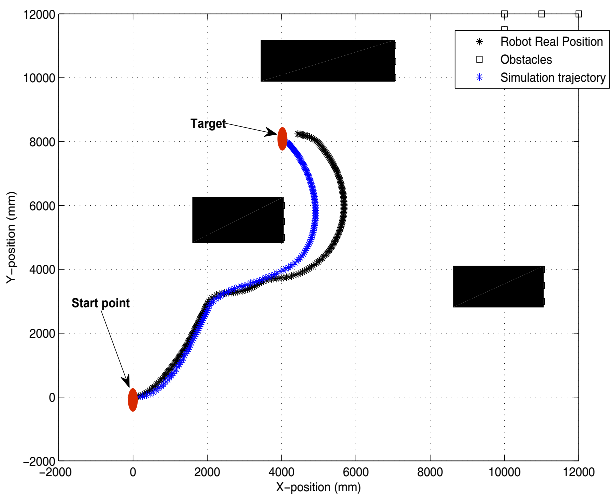

Fig. 10. Navigation with obstacles on one side.

Condition D The user had different objects disposed on two sides (Fig. 11). Then he was also to choose either a trajectory to follow either a target to reach.

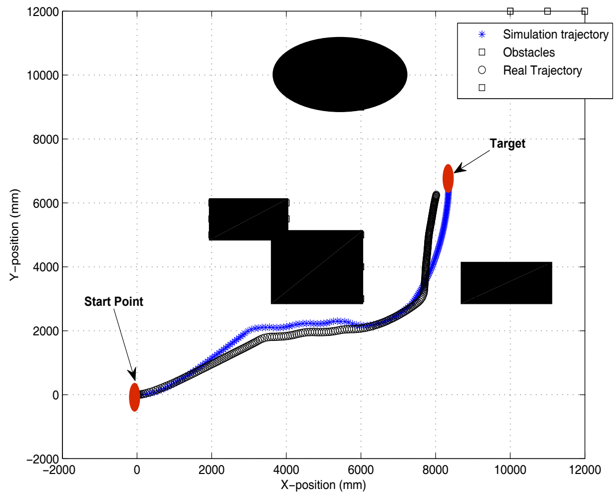

Fig. 11. Navigation with obstacles on two sides.

In this experiment, the tasks was chosen in order to evaluate the intention of the user when the wheelchair is navigating autonomously using a reactive obstacle avoidance algorithm. The intention means the feelings of fear, encourage, frustration. That's has a great importance especially when the interface shows in real time the current position of the wheelchair beyond the obstacles. The obstacles used in the experiment are wooden objects. For example, the corridor is composed from four wooden walls in order to prevent injury to the user and equipment.

In the first test, the user places the target point in the interface and initiated the navigation of the wheelchair in environment with a corridor. Three trials were performed and are presented in Figures. 7 and 8. while in figure Fig. 10, the participant placed two waypoints in the environment added to the previous start and end point. The trials are carried out by adopting different start points defined by the coordinates ($X = 13000mm, Y = 0mm$) and three orientations ($\theta = 0, \theta = \frac{\pi}{2}, \theta = \pi$). The driver aims to reach the target defined by the coordinates ($X_T = 1000mm, Y_T = 4000mm$). The adopted route is complicated with obstacles on both sides. In Fig. 7 where the robot initial orientation is 0, we notice that the robot is initially reaching the target. When the detected obstacles become inside of the security zone, the robot starts to avoid them, follows-up the walls until reaching the target. In the second scenario presented in Fig. 8, the user has changed his initial orientation and attempts to reach the same target.

Initially, the experimenter positioned the interface towards the participant at an appropriate position. Then he initiated the communication between the laptop and the wheelchair and display the interface to the user. The experimenter explained the task to execute in the current experiment condition and trained the participant to operate with the interface. The execution began when the experimenter prompted the user to choose a target to achieve and ended when the wheelchair reached it. The duration of each trial averaged forty five minutes.

Data was collected basing on post-trial questionnaires and the computer files. The questionnaire asked questions about which kind of navigation (totally autonomous or path following) the user liked most, which navigation they liked least, and suggestions for improving the proposed algorithm. The computer files saved : wheelchair velocities and position, crossed distance and the time needed from target prompt to user selection and the time from the wheelchair movement to the target reached.

5. Results and Discussion

Hypothesis 1 (ease of use): The target selection time and the initiate of move was be used as a measure of ease of use of the interface. The average participant's from prompt to pressing the button of navigation ranged from 9 seconds to 21.12 seconds (table. 2). Participants have operated better in Condition A (moving in corridor with a totally autonomous wheelchair) than Interface B (selection of trajectory). As for the condition C and D, the participants were operated easily for the both cases. For each participant and in the six experiments (three trials for condition A and three trial for the three remaining conditions), they expressed their preference for particular condition B where they choose their own trajectory.

Hypothesis 2 (obstacles in one side preference to two sides: Basing on selection time analysis (table. 2) and the level of fear summarized in (table. 3), we notice that participants liked the navigation through obstacles in one side than in two sides.

Moreover, the first open-ended questions (Which obstacles disposal did you like more? Why? and Which disposal did you like less ? Why?). Disposal in the condition C was the most liked with four positive comments.

Hypothesis 3 (totally autonomous navigation preference to partially guidance): In statistical analysis over fear level (table. 3), we notice that users were found to have more confident in navigation with condition B (partially autonomous navigation) than navigation with condition A (totally autonomous navigation), and condition C than D. This due to the use of a reactive obstacle avoidance algorithm that supposed the obstacles are unknown. When the user is near to the obstacle, he feels fearing and have not confident on the wheelchair autonomous navigation, despite it succeeded to avoid the obstacles and reached the target. Besides, we notice that the greater the number of trials the least level of fear.

In fact, due to the little sample size and minor abilities problems of users in this experiment, we do not want to make generic claims. In future works, the users will contain a more important disabilities.

6. Conclusion

The proposed pilot system have a series of assumptions to be taken into account in future works. Despite it ensures an important level of autonomy to the robot the level of the user safe navigation is yet minor. The time selection and the level of fear Sproved that the participant feel more confident where he interacts with the interface by choosing her own path to achieve the target. Despite these limitations, this paper has proposed generic guidelines for reactive guidance with user interaction in the case of disable people.

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Tab. 2. User time to target selection and navigation starting. Trials are grouped into tuples. For example T(x,y) means the trial x take y seconds

	ConditionA	*ConditionB*	*ConditionC*	*ConditionD*
$P1$	$T(1,15), T(2,12), T(3,10)$	$T(1,18)$	$T(1,10)$	$T(1,11)$
$P2$	$T(1,21.12), T(2,15), T(3,9)$	$T(1,21)$	$T(1,12)$	$T(1,12)$
$P3$	$T(1,17), T(2,15), T(3,12)$	$T(1,19)$	$T(1,12)$	$T(1,12)$
$P4$	$T(1,16.32), T(2,12), T(3,9)$	$T(1,18.2)$	$T(1,9)$	$T(1,9)$

Tab. 3. Participant fearing level (zero low to ten high)

	ConditionA	*ConditionB*	*ConditionC*	*ConditionD*
$P1$	$T(1,10), T(2,7), T(3,4)$	$T(1,2)$	$T(1,4)$	$T(1,7)$
$P2$	$T(1,10), T(2,10), T(3,5)$	$T(1,1)$	$T(1,5)$	$T(1,7)$
$P3$	$T(1,9), T(2,7), T(3,3)$	$T(1,1)$	$T(1,4)$	$T(1,8)$
$P4$	$T(1,10), T(2,10), T(3,2)$	$T(1,2)$	$T(1,3)$	$T(1,7)$

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