

Real-time Obstacle Avoidance for Intelligent Wheelchairs



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■ Motivation

Find solutions to assist handicapped people who are unable to operate classic electric wheelchairs by themselves in their daily activities.

■ Main Goal

- ✓ Design a control methodology to assist wheelchair's users (Shared Control)
- ✓ Avoid obstacles in real-time
- ✓ Increase user safety
- ✓ Improve user safety perception
- ✓ Low memory and processing consuming algorithm.
- ✓ Based on low cost sensors

■ Hypothesis

- I. The shared control paradigm does provide significant reduction in the number of collisions .
- II. The shared control paradigm does provide significant improvement in the user safety perception.
- III. The shared control paradigm does help the user during navigation tasks.
- IV. The wheelchair has the same behavior in the real and the simulated environment.

- *Proposed methodology*

This approach is an extension of the potential field concept;

The robot is considered immersed in a field of forces generated by the target (attractive force) and by obstacles (repulsive forces);

The resultant robot behavior is obtained by the sum of all attractive and repulsive forces at a robot's given position;

Does not build a map the environment;

Instead, each ultrasonic range reading is treated as a repulsive force;

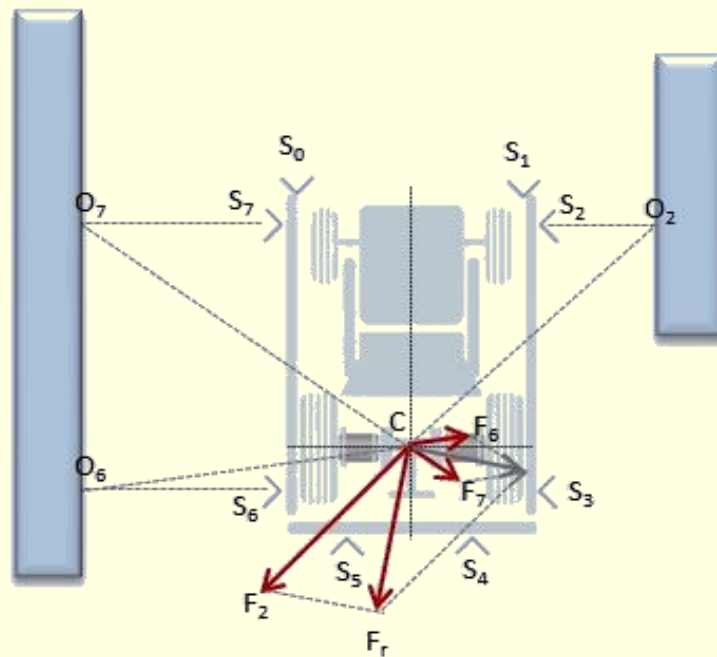
Forces are computed in real-time;

- Proposed methodology

The position of obstacle O_i is computed as the measured distance D_i under the acoustic axis of the sensor.

The direction of each repulsive force is determined by the direction of σ_i .

$$\sigma_i = \tan^{-1} \frac{O_{iy}}{O_{ix}}$$



Each repulsive force is dependent of the distance to the object and to the wheelchair speed

$$|F_i| = \alpha * \exp(-\beta * D_i + \omega * S) * |F_a|$$

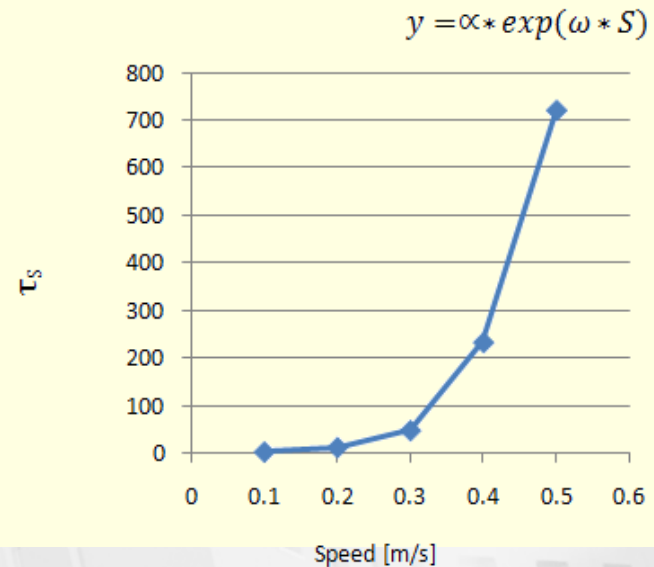
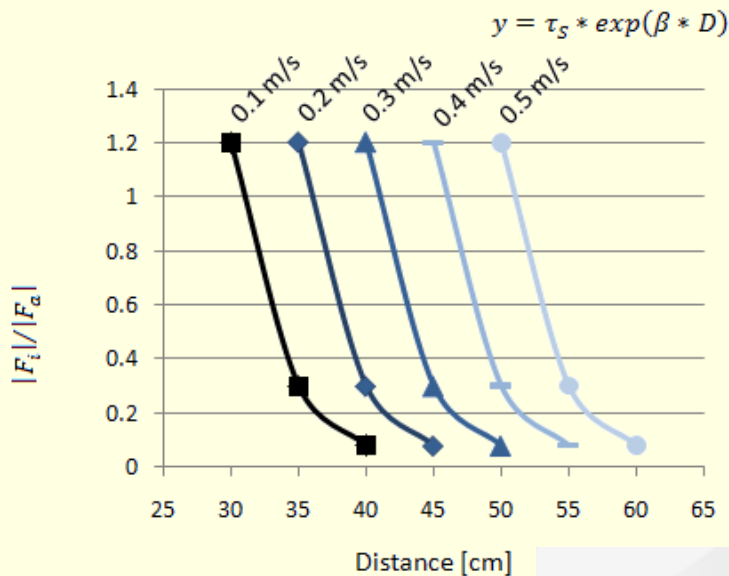
Where:

α, β, ω Positive constants deduced from the desired safety range.

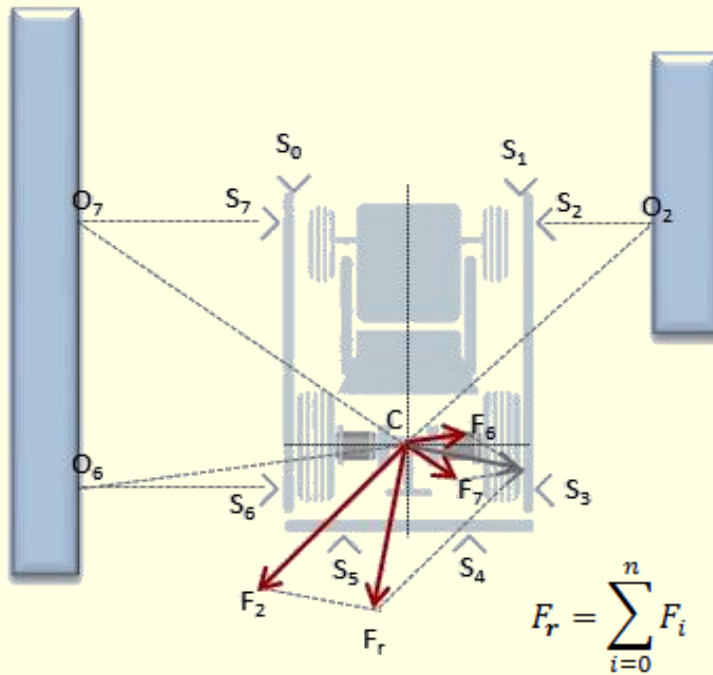
F_a Attractive force

D_i Distance measured by the sensor S_i

S Wheelchair's speed

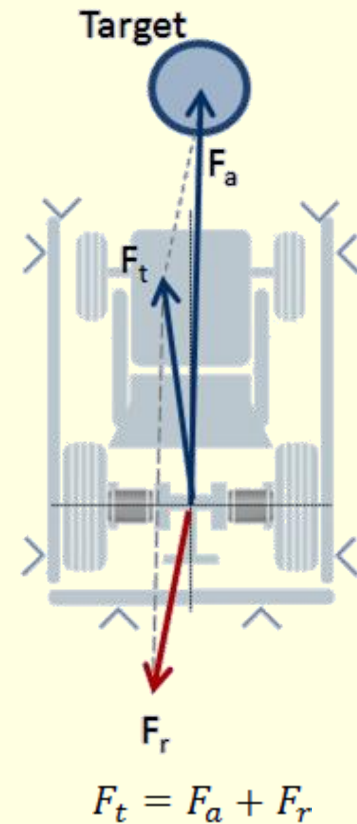


Proposed methodology



Where

- F_i Force yielded by the object O_i sensed through the sensor S_i
- F_r Resultant repulsive force
- F_a Actual attractive force
- F_t Force that drives the robot



- *Evaluation tests*

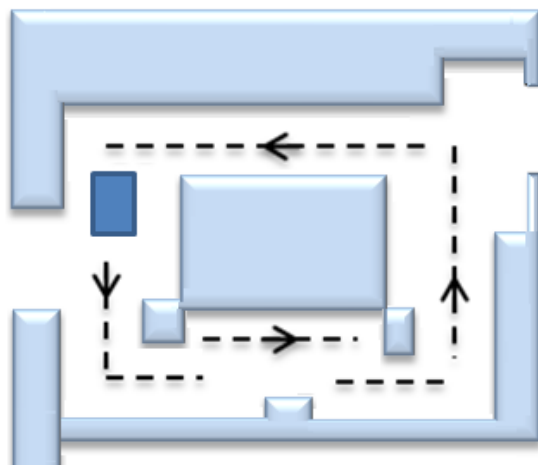
6 volunteers aged between 26 and 39 years old (30 in a near future).

Composed of 1 set of 4 drive tests.

Driving interface based on the user's head position.

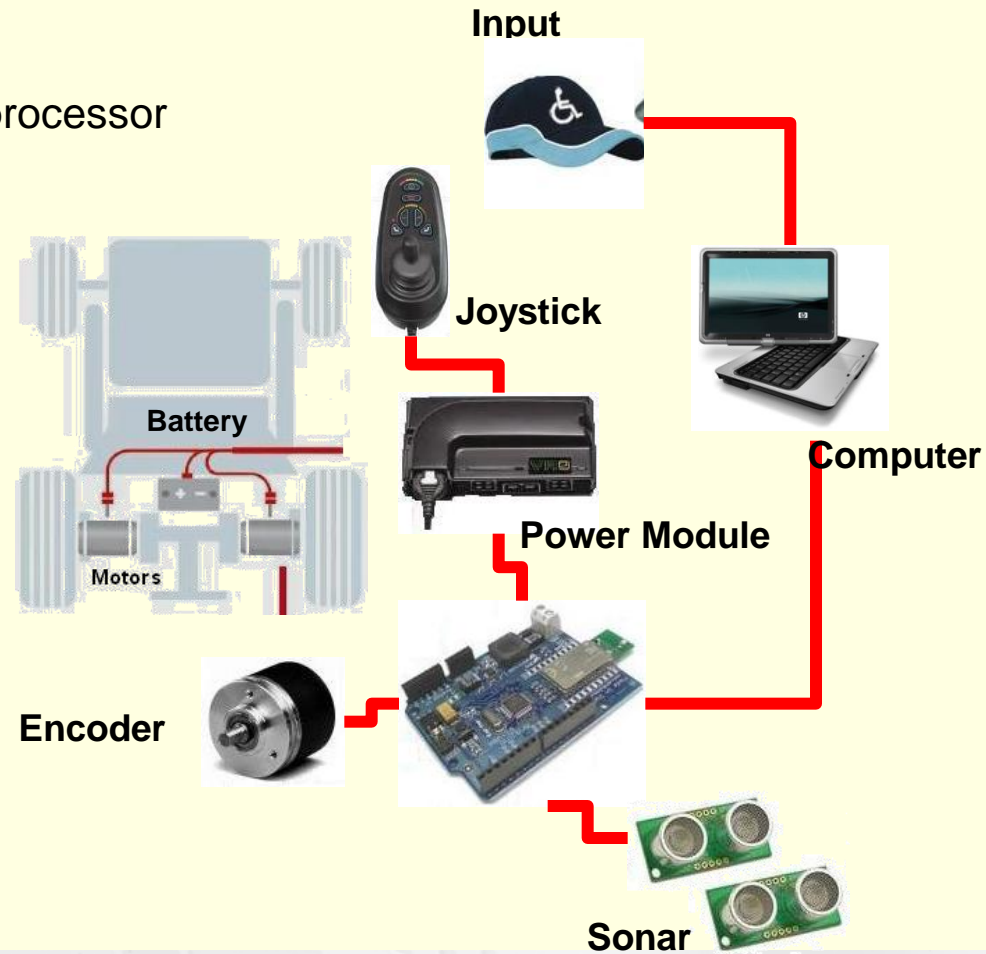
User's goals:

1. Drive safely through the predefined path.
2. Finish each lap as fast as possible.



■ Prototype

- ✓ Ring of eight sonars
- ✓ Two encoders
- ✓ Embedded ATmega1280 microprocessor
- ✓ 128 Kb of Flash memory
- ✓ Algorithm cycle of 80 ms



■ Protocol

Defined to standardize the results of both tests:

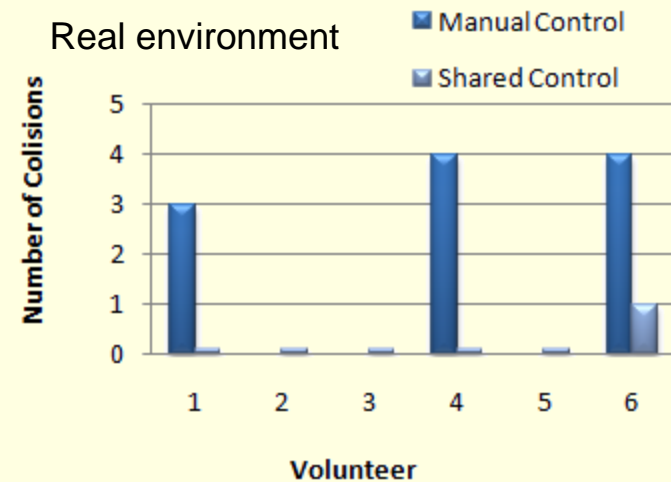
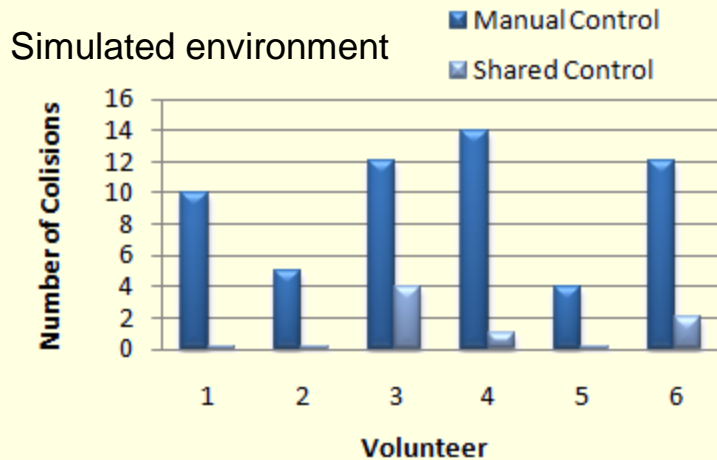
- I. Volunteers have been instructed about test procedure and about their objectives.
- II. 10 minutes trial in a simulated environment (experiment the wheelchair and make the adjustments in the special human-machine interface) .
- III. Drive the wheelchair (1 lap) through the circuit in the simulated environment with the manual control paradigm.
- IV. Drive the wheelchair (1 lap) through the circuit in the simulated environment, but with the assistance of the shared control.
- V. Drive the wheelchair (1 lap) in the real environment with the manual control.
- VI. Drive the wheelchair (1 lap) in the real environment with the shared control paradigm.
- VII. Post-task questionnaire (to evaluate the user safety perception).

■ Two sections of six questions using a five-point Likert scale item
(1 = Strongly disagree, 2 = Disagree, 3 = Neither agree /disagree, 4 = Agree, 5 = Strongly agree)

- I. I feel comfortable when driving the wheelchair.
- II. I feel that I have the control of the wheelchair behaviour.
- III. It is easy to drive the wheelchair in cluttered spaces.
- IV. Driving the wheelchair requires little attention.
- V. The wheelchair has the same behaviour either in the simulated and the real environments.
- VI. I believe that the shared control helped me during the navigation task.

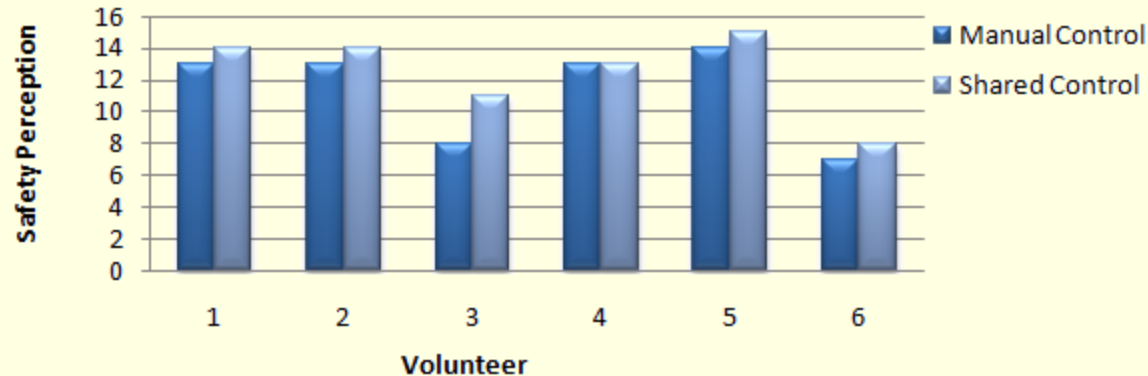
The user safety perception was treated as an indirect variable measured through the sum of the points of the first four statements.

- Number of collisions (paired 2-tailed *t*-student test - H_0 $p \leq 0.05$)



- ✓ In the simulated environment, results ($t= 6.028$, $p= 0.002$), provided statistical evidence that the shared control is effective in reducing the number of collisions.
- ✓ In the real environment, results ($t= 2.582$, $p= 0.049$) provided statistical evidence that the shared control is effective in reducing the number of collisions.

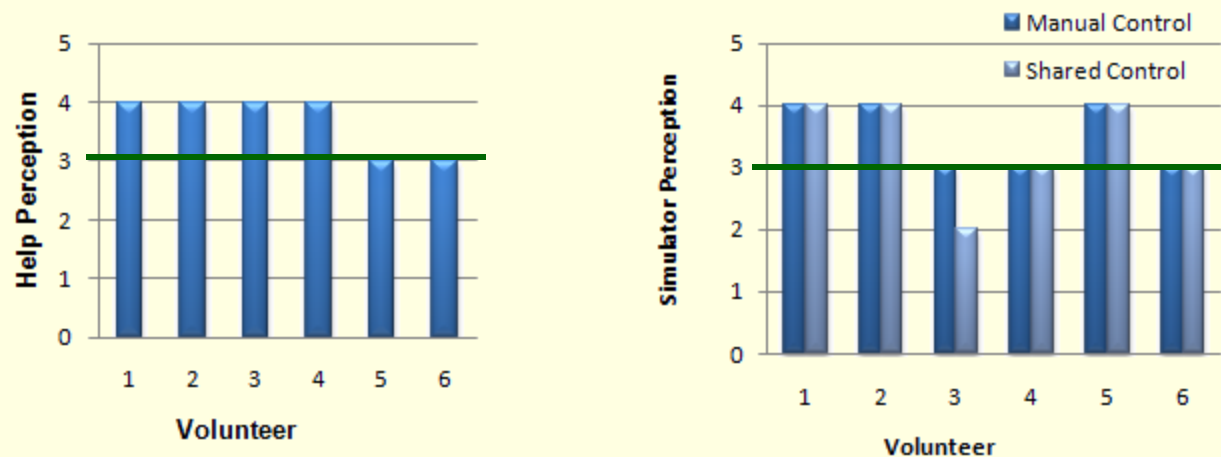
- Safety perception (paired 2-tailed *t*-student test - H_0 $p \leq 0.05$)



✓ Results ($t = -2.907$, $p = 0.034$) indicate statistical evidence that the shared control is effective to improve user's safety perception.

- Simulator and Help perceptions (paired 2-tailed *t-student* test - H_0 $p \leq 0.05$)

(Likert scale \rightarrow 3 = Neither agree /disagree)



✓ *t-student* results ($t = 3.162$, $p = 0.025$) provided evidence that volunteers indeed felt that the shared control paradigm helped them to drive the wheelchair.

✓ It was not possible to state with a confidence level of 95% that the wheelchair has the same behaviour in the real and simulated environments for both manual and shared control paradigms.

■ Conclusions:

- ✓ Real-time obstacle avoidance algorithm, low overhead.
- ✓ Independent of a localization system.
- ✓ Narrow corridors navigation.
- ✓ Hypothesis I, II, III were accepted.
- ✓ The approach is very sensor-dependent.
- ✓ Presence of two small blind spots for object closer than 25 cm (one at each side of the wheelchair).

■ Future work:

- ✓ Increase the wheelchair's simulator realism.
- ✓ Fix the wheelchair's blind spots.
- ✓ Implement Kalman filtering to reduce sensors noise.
- ✓ Increase the number of volunteers.
- ✓ Test the algorithm in impaired people with different diseases.

Questions



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