Intelligence Agent Control Strategy Toward Eight Wheel-legged Wheelchair Robot

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Abstract. The wheelchair robot as old and disabled people helper has becomes an instead of walking tool and changes their life. However, owing to motion mechanism complexities its controller research still faces a serious challenge to the development of the wheelchair robot. This paper addresses a cooperative strategy of developing efficient robotic control system in the presence of modeling intelligence agent methods and techniques. The configuration of eight wheel-legged wheelchair robot is given, and it includes three main modules, that is, the foreleg module, the hindleg module, and the seat module. They compose three executing agents for controlling wheelchair robot stair-climbing postures. An intelligence agent framework is used to describing the process of wheelchair robot work. The paper presents the agent control strategies to be used as solving stable cone for wheelchair robot stair climbing. The simulation result has been analyzed to enhance the relationship between human behavior sensing and obstacle detection computing.

Introduction

In the last few years service robots have been used for deliver meals, assist shopping, and pour drinks on public houses. In order to realize intelligence control, a multi-agent framework was proposed to describe the process of multi-agent coordination work, in which each agent can feel its environment and make response to it [1-2]. In addition, a port-based behavior graph is presented to model climbing robot and route planning. A multi sensor intelligent wheelchairs, a force reflective feedback system was developed by [3] to assist monitor robot act.

In order to improve obstacle climbing ability of wheelchair robot, [4] developed a wheelchair mechanism with high single step capability, and it makes front and rear wheel clusters connected to the base via powered linkages to facilitate stair climbing and descent. A smart wheelchair design was explained in [5] to aid persons with special needs and disabilities. This employs several components such as infrared sensor, sonar sensor, etc., to make a normal powered wheelchair as a smart wheelchair robot.

Kinematic model of stair climbing wheelchair during ascent and descent is presented in [6]. Two decoupled mechanisms were used in each axle. One mechanism takes care of climbing the steps and other takes care of the slope. Port-based ontological methodology was proposed to use for generating robot mechanism scheme, and a genetic algorithm was described to support robot motion control [7].

Three Main Modules of Wheelchair Robot

Three modules of stair climbing wheelchair can be considered as three different functions. Each has a specific requirements, and their coordination work can implement stair climbing and obstacle crossing. Figure 1 presents three module of the wheelchair configuration.

The Foreleg Mechanism Module (FMM)

The foreleg module includes left frontal leg and right frontal leg, and they can autonomously realize stair ascent and decent through adjusting their positions and orientations. Their function is as follows:
- Both frontal leg simultaneous lifting movement
- They work as two balance fulcrum of the trunk
- Coordination work with the other module unit

The Hindleg Mechanism Module (HMM)

The hindleg module includes left hindleg and right hindleg, and they can change the direction of applying force at stairs and obstacle through adjusting their positions and orientations. Their function is as follows:
- Both hindleg simultaneous lifting movement
- They can change the direction of applying force
- Coordination work with the other module unit

The Seat Mechanism Module (SMM)

The seat module can change the angle of the seat mechanism as opposed to the chassis in order to keep the user comfortable through adjusting their positions and orientations.

Above-mentioned three modules integrating multi-sensor feedback into realtime control loops. It is also possible to combine some of control modes and algorithms in order to adapt the interface as much as possible to the specific needs of different users.

The Intelligence Agent Framework (IAF)

Three function module is corresponding to three executing agents which can coordinationly implement some operations, such as, stair climbing, obstacle crossing, over the ditch, and so on. Therefore, user-oriented IAF is designed to control the wheelchair robot in two different modes: manual operation movement mode and autonomous movement mode. Here, joystick agent can realize two mode setting. By the usage of the former control mode, only the joystick is used for operating wheelchair robot through the user. He/She operates the wheelchair robot motion only by the feeling. But experience is the main factor for manual mode. Whereas, in the latter mode, the control is completely delegated to the computer, and movements in the entire workspace of the wheelchair robot are allowed, which includes joint space and Cartesian space. However, motion workspace of the robot is limited as opposed to stairs or obstacles from sensor feedback information. Figure 2 is corresponds to the autonomous movement control mode. The user-oriented robot movement mode is available through determined rules, and it allows compliance with certain uncertainty, but execution becomes tedious for the new users. Execution of autonomous tasks avoids user interference, but it needs preprogramming execution, yet such system cannot meet with all of the users’ requirements. Port-based ontology knowledge modeling is used to settling for execution program tasks for a nontechnically oriented person [1, 2]. The confliction of execution tasks may appear among different agents, and coordination work will becomes very important. Each agent has a certain flexibility to deal with its own tasks while minimizing the amount of time it takes to perform a task. They share
knowledge base and has reasoning ability which they can interact with joystick agent shown in Figure 2.

![Figure 2. The framework of intelligence agents.](image)

**Intelligence Agent Control Strategies**

Agents have a certain ability of reasoning and solving problems. They can implement some tasks that the users assign it. For example, gesture act requirements, safety requirements, comfortable requirements, etc. in which safety issues are a key factor for the wheelchair robotics.

**The Joystick Agent Control**

The joystick agent has two kind of work modes, that is, manual and autonomous modes. It has a memory function. It can remember motion requirements that has finished before. In manual mode, it can acquire the control power for wheel robot manipulation, and the new user can operate it from the joystick agent guide. However, in an autonomous mode, the joystick agent is completely subject to program control. It eliminates artificial interference, and keeps motion safety, only if the user remove an autonomous mode.

**Communication Agent**

When the agents work, they will need to obtain much information for agent decision. It plays an important role for communication agent. It can provide the interactive function among agents by a standard syntax for message and use the knowledge query and manipulation language (KQML) for different port agent communications [8]. Here, it transmits the contents from data packet format with standard syntax, such as the parameters of motor motion, sensors, clutch, and so on.

**Three Executing Agent Control**

In the process of system work, three executing agents coordinately work to solve the port behavioral model for adjusting wheelchair mechanism positions and orientations. Each agent description is as follows.

- **Foreleg agent** It can sense stair tread and kick distance message. In order to avoid collision with stairs, it can implement obstacle avoidance when the wheelchair robot climbs stairs.
- **Hindleg agent** It can change the angle of applying force opposed to stairs, and decrease the torque to climb stairs. And it works as two balance fulcrum of the trunk.
- **Seat agent** It can adjust the angle of the seat to make the user safety and comfortable. At the same time, it coordinates the other agents to keep the stability of the wheelchair robot work.

Above-mentioned three executing agent can obtain parameters from sensors, and they will be input fuzzy nerve net, and the hidden layer is used for solving behavioral graph models, and transmits results to next behavior graph until output layer, and the results are some control parameters and act requirements, such as distance, time, angle, etc.
The Process of Stable Cone Solving

When the wheelchair robot climbs stairs or obstacles, safety must be guaranteed by the consideration that the center of gravity (COG) keeps within its stable cone range opposed to the stairs. The robot trunk must maintain 4 points of contact with the stairs and be configured in such a way as to provide acceptable stability margins at all times shown in Figure 3. The wheelchair robot must be safe in every 3-D structural environment. The wheelchair robot velocity of climbing stairs is slow for rider comfort, about 3 steps/min. It is much faster for ground motion, but it becomes slow action when near the stairs or obstacles.

According to Newton theorem and moment of momentum conservation, we can obtain the force and moment balance equations. Considering stability and safety, three needed conditions is as follows.

- Avoid corner point tipping \( \psi > 0 \), and the COG falls in the stable cone edge line GP.
- Avoid edge line tipping \( \gamma > 0 \), and the COG falls within the cone bottom edge line \( P_iP_j \).
- Stability seat angle \( \Omega \) change interval \( \Delta \Omega \leq \pm 3^\circ \), and it makes the riders comfortable.

By sloving the force and moment balance equations we will obtain the angular size of applying force of \( \gamma_1, \gamma_2 \) when the angle \( \varepsilon \) of stairs changes.

Simulation Result Analysis

Three executing agents receive operational orders from the joystick by communication agent. They have solving and reasoning ability when receive orders, such as stable cone solving, avoidance detection. Tab. 1 gives agent function terms when the robot climbs four steps, in which the time stands for total time of each agent effective climbing motion. Actions present action time. The com_data stands for the times of communication agent implement data send/receive transmission. Different data may appear among different executing agents in the process of wheelchair robot work. Figure 4 presents the displacement of foreleg center of gravity. Also, through stable cone solving, we can obtain the relation surface of COG, applying force, and angle \( \gamma \) shown in Figure 5. These curve and surface indicate that the wheelchair robot work in normal ranges.
<table>
<thead>
<tr>
<th>Agents</th>
<th>Functions and action terms</th>
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<tbody>
<tr>
<td>Manual</td>
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<td>time</td>
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<td>Joystick</td>
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</tr>
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<td>Foreleg</td>
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<td>Yes</td>
</tr>
<tr>
<td>Hindleg</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Seat</td>
<td>No</td>
<td>Yes</td>
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Figure 4. Foreleg cog displacement changes.
Figure 5. Relationships of cog, force and angle.

**Summary**

An intelligence agent control system has been successfully built to operate in the negotiation of different agents towards stairs both up and down. A numerical model is established and simulated for eight wheel-legged wheelchair robot. An intelligent agent coordination process is described to solving stable cone model. At last, we obtain the results of confidence, and they can be used to describing the process of stair-climbing and obstacle-crossing of the eight wheel legged wheelchair robot. Future work is required to extend stair-climbing techniques towards some standard staircase steps.

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**References**


