

# **Assistive AI with Headset Control for Limited-Mobility Users**

## Related Work

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# Introduction

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Autonomous robotics is a well-trodden path and recent legislative pushes to license autonomous vehicles in Nevada point to a future where autonomous vehicles become an even more prevalent part of daily life. Beyond just the convenience of having cars park themselves, propositions regarding greater safety and empowering less mobile groups (like the elderly) to maintain greater independence also underscore the quality-of-life improvements such systems can offer. Fortunately, this research has also been applied to smaller platforms like wheelchairs, and can bring many of the same benefits to individuals with even more limited mobility. Alternative input devices can even provide control of these systems to users otherwise unable to use conventional keypads and joysticks. This thesis explores the combination of electroencephalography (EEG) headsets with an assistive AI as part of a control system for a wheelchair.

## Related Work

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Being so heavily explored, one of the initial challenges was identifying system architectures that worked well, rather than those whose *further work* sections alluded there was much to be desired. The cost constraint also represents another challenge since many wheelchair systems feature \$5,000+ laser ranging systems. Though these afford considerable situational awareness to the system, one of the goals of this thesis is to implement a system with similar functionality at a lower cost. Low cost sensors have the consequence of increasing the degree of uncertainty in the platform's internal world representation, also requiring models which are flexible in reasoning amid uncertainty. Partially observable Markov decision processes, an extension of Markov chains, are aptly suited to this task, though their flexibility comes at a price: they are PSPACE-hard [4]. Nonetheless, approximations can be used to reduce the scope of the state distributions and bring the benefits into computational tractability.

### **Xavier**

Fortunately, there have already been successes leveraging partially observable Markov decision processes (POMDP) in the context of robotic navigation. One platform in particular, named Xavier, logged over 60 kilometers of travel in an office setting, utilizing a partially observable Markov decision process with over 3,000 states [2]. It exhibited strong resilience against sensor failure by being able to reevaluate and dynamically adjust its state periodically. Most impressive was the plug-and-play manner in which the POMDP was implemented. This allowed the POMDP-based navigation layer to be swapped with a more conventional landmark-based navigation layer for comparison on an otherwise identical robotic platform. Testing showed the later to have an approximate success rate of 80% with the POMDP-based solution edging it out at 93%. The overall success of this platform and the research team's positive evaluation of its dealings with sensor failure and positional uncertainty lend strong credibility to the potential effectiveness of POMDP-based approaches to navigation in dynamic environments. Xavier's decision process is still tiered, where behaviors become increasingly sophisticated as lower level checks (like proximity sensors) return within certain ranges. Breakdowns at

lower levels can render the robot substantially impaired and undermine higher navigational goals. Migrating to an architecture where sensor processing is decentralized and driven by agent consensus could make the system even more robust in the event of failure and opens up the platform to even greater extensibility.

## **RHINO**

Another robotic platform, named RHINO, used Markov models purely for localization within the environment [1]. Though I intend to follow the approach of Xavier which used POMDP more explicitly for navigation, RHINO's unique environment draws attention to certain potential sources of error in localization not accounted for in Xavier. While relying on a conventional array of sensors (stereo cameras, SONAR, and laser ranging), RHINO was situated in a museum for testing, giving it certain obstacles which were "invisible", at least to its sensors. Glass casings around exhibits were essentially undetectable and created discrepancies between SONAR and laser readings which might otherwise seem like an errant situation. The use of Markov localization allowed RHINO to nonetheless navigate the environment. Taking into account largely "invisible" obstructions which a wheelchair may encounter (i.e. chain-link fencing or glass panes next to doors) will be key to the user experience and underscores the need to ensure no single agent is afforded too much control over the system. RHINO's use of multiple sensor types for a single function provides not only a level of fault-tolerance, but also the opportunity to detect obstructions that certain types of sensors are more prone to missing. While in principle this makes sense, finding sensor combinations which can reliably detect obstructions like chain link fences is something that will need to be addressed.

## **Collaborative Wheelchair Control**

There were quite a few papers by Yoshinori Kobayashi which centered on trying to make wheelchairs more useful in healthcare settings [5][6]. The goal was to empower users, by not needing to be pushed by someone who would be perceived as a caregiver, and allow the wheelchair to travel alongside someone, as is more common in interactions with friends. Though their sensor systems were just as elaborate as those of Xavier and RHINO, the emphasis was not on strictly autonomous operation. Rather, the goal was to have the wheelchair intelligently follow someone walking and respond intuitively to situations like the leader holding open a door or needing to pass others single-file in a hall. While care facilities are not the intended target of this thesis, people following behaviors may prove to be very effective strategies in densely populated environments like sidewalks or hallways. Since the system must prevent collision with pedestrians, and in many cases it could be advantageous to implement following behaviors. As the platform will already be equipped with depth cameras, implementing these features is within the realm of possibility. Feedback seemed positive from users, though issues like the wheelchair turning away from the caregiver in certain situations were noted as room for improvement.

## **HaWCoS (Hands-free Wheelchair Control System)**

The HaWCoS appears to be one of the earlier implementations of EEG for wheelchair control [3]. It did not aim to offer a coupled autonomous mode, which is a key area of difference, but does make do with very modest resources by modern standards, running off a Pentium 3 laptop. EEG input, though

noted as having inherent problems with noise and model matching, appeared to have been an effective input mechanism for users with severe disabilities. Joystick input was unsurprisingly faster, but in testing, the researchers found that EEG control only took on average 48% longer to complete the same paths. For users with few input options, those results are quite promising, and hopefully with the integration of an assistive AI to deal with problem cases (like minor adjustments to keep travelling straight down a hall) the time disparity could be shrunk down even further.

### **Combining Strengths**

Each of the noted systems offers an important insight into potential problems for both autonomous and guided navigation. This thesis aims to take the strengths of each in the hope of mitigating concerns noted in each of their further work sections. Responding intelligently in a dynamic environment will require well developed heuristics, and I believe in combination, these systems along with others could perform quite well.

# References

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