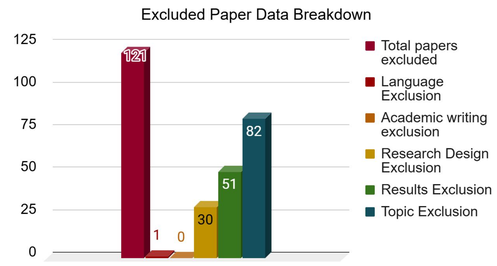
Preventing Abuse Against Service Robots

ES302 Robotic Systems Final Project by Ryan Comisky - Integrative Engineering, Robotics

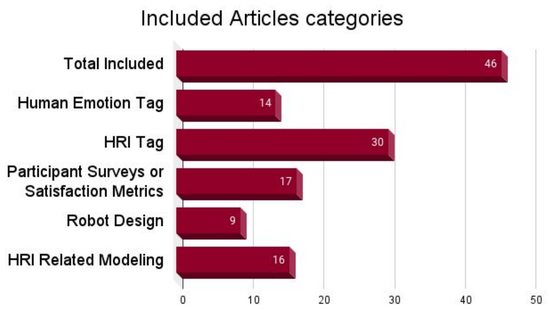
Abstract

As the use of service robots ever increases in popularity, it's important to consider how humans interact with them. It is equally important to consider how to improve robot design to make service robots safer, more efficient, and less prone to mistreatment. There is currently extensive research into human-robot interaction (HRI), but less into preventing abuse of service robots.[1] This research plans to answer the question: How can service robots be developed to prevent and withstand mistreatment?

Prior Work

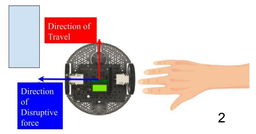


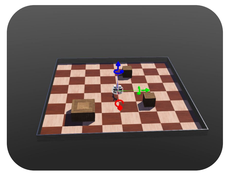
Prior to the study, a literature review was conducted in the field of HRI and social robotics. 174 papers were initially found after inputting a custom search string into the IEEE Xplore database. These were then screened for five criteria as shown in the graph above.



After the initial article screening, 46 papers were screened and categorized according to the tags shown in the graph above. These helped to sort possible papers into distinct categories.This also acted as a secondary screening before data collection and extraction.

Methodology



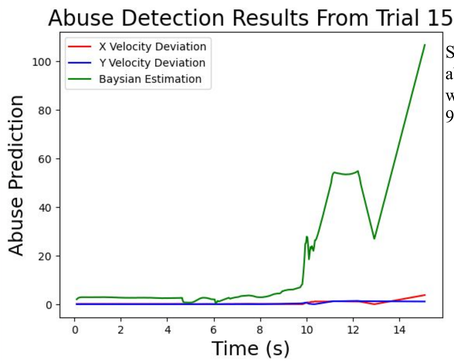


The goal of the study was to simulate robot abuse and test detection methods. Equations were developed to compare x and y velocities based on the calculated measurements from odometry and GPS. ovX and ovY denote odometry, while gvX and gvY denote GPS values. Constants were determined by taking the average deviation of multiple runs. Fifteen trials of fifteen seconds were taken to adequately test the accuracy of models created.

Xdeviation abuse = $|gvX - ovX| > threshold$
Ydeviation abuse = $|gvY - ovY| > threshold$
Bayesian Estimation = $((xError * yError)/2) * ((Xdeviation + Ydeviation)/2))/0.01$
xError = 0.93, yError = 0.94, Bayesian error = 0.01, range = 0.7

For x and y deviation, the odometry velocity was subtracted from the GPS velocity to ensure that abuse deviation was detected as opposed to the robot being stuck. All constants were found using the average attempts without abuse, x and y errors are referring to success rate, where the Bayesian value is the error. Range acted as a threshold value for the deviation abuse detection.

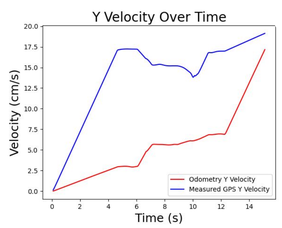
Results

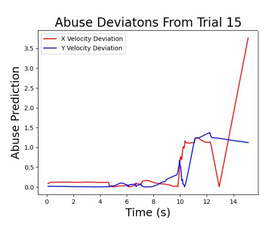


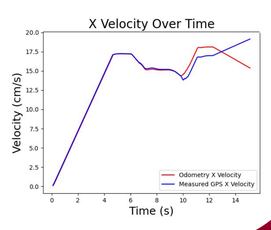
Simulated abuse force was initiated at 9.4 seconds.

Raw data collection in addition to simulation data

Trial	time initiated	Bayesian abuse?	Deviation abuse?	Both?
1	3.4	Y	Y	Y
2	14.2	Y	n	n
3	10.7	Y	Y	Y
4	6.3	Y	Y	Y
5	7.1	Y	Y	Y
6	12.8	Y	Y	Y
7	4.7	Y	Y	Y
8	11.2	Y	Y	Y
9	0.4	Y	Y	Y
10	7.5	Y	n	n
11	1.8	Y	Y	Y
12	9.8	Y	n	n
13	2.8	n	Y	Y
14	6.4	Y	Y	Y
15	9.4	Y	Y	Y
Accuracy totals		14.0/15.0	12.0/15.0	12.0/15.0
Percentage		93	80	80







Discussion

Over fifteen trials, the combination of algorithms detected abuse 80% of the time. Using only Bayesian estimation abuse was detected 93% of the time. Using a combination of velocity deviation and Bayesian estimation had a lower abuse detection rate than using Bayesian estimation by itself.

Conclusion

To answer the original research question, we can prevent abuse by using Bayesian estimation and velocity deviation. Although Bayesian estimation was more accurate in detecting abuse than velocity deviation, using these two algorithms together acts as a robust framework for abuse detection. Overall this study worked as a well-defined first attempt at abuse detection. As shown in the x and y velocity graphs, the odometry-based velocity worked as a relatively accurate measure of robot abuse. At the initial time the force is applied, there is significant deviation from the GPS velocity to indicate abuse. This works well for when the force is initially applied. However, this could lead to inaccuracies for secondary forces or as a measurement of when force is no longer being applied to the robot.

Future Work

In an expanded research study in the area, the use of additional sensors like an Inertial Measurement Unit (IMU) or a camera could further increase the accuracy of abuse detection. It could also be beneficial to run this same experiment on a real Romi with a longer duration to further test the created algorithms.

References

1. [1] M. Fooladi Mahani, L. Jiang, and Y. Wang, “A Bayesian Trust Inference Model for Human-Multi-Robot Teams,” Int J of Soc Robotics, vol. 13, no. 8, pp. 1951–1965, Dec. 2021, doi: 10.1007/s12369-020-00705-1.
2. Attribution for hand image:Hand Vectors by Vecteezy

Acknowledgments
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