Designing a minimalist socially aware robotic agent for the home

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Abstract

We present a minimalist social robot that relies on long time-series of low resolution data such as temperature, lighting, sounds and collisions. Our goal is to develop an experimental system for growing *socially situated robotic* agents whose behavioral repertoire is subsumed by the social order of the space. To get there we are designing robots that use simple sensors and motion feedback routines to recognize different classes of human activity and respond.

We use the *Katie Family* of robots, built on the *iRobot Create* platform, an *Arduino Uno*, and a *Raspberry Pi*. We describe exploratory tests that allow us to develop hypotheses about what objects (sensor data) correspond to something known and observable by a human subject. We use machine learning methods to classify three social scenarios, demonstrating that it is possible to detect social situations with high accuracy, using the low-resolution sensors from our minimalist robot.

Objectives

1) **Develop a privacy-respecting** robot with low-resolution sensors that could coexist with humans in a home

2) Demonstrate **the ability of the robot to distinguish between social situations**, thus demonstrating the capacity of such a robot to navigate the social environment where it is embedded

3) *Future Work:* **Allow interaction and adaptive learning** to develop the robot's understanding of its *social umwelt*

Methods

Three human interest scenarios:

- Scenario 1: the experimenter walks by the robot (proxy for lack of interest)
- Scenario 2: the experimenter circles the robot (proxy for interest in interacting)
- Scenario 0: no one entered the room.

In all scenarios, the robot slowly turns in a circle to scan the room. Each scenario was run 10 times at 5 different proximities, marked on the floor of the room: contact, 1-20 cm, 21-40 cm, 41-60 cm, and 61-80cm. Each run is referred to as an *experiment*. The experiments were conducted over the course of two days in random order, using random doors as the entrance and exit of the room. Random Forest, SAMME Boosting, and Logisitc Regression classifiers (and two null-models) were tested through 10-fold cross validation, with classification of all three scenarios and binary classification between scenarios 1 and 2,

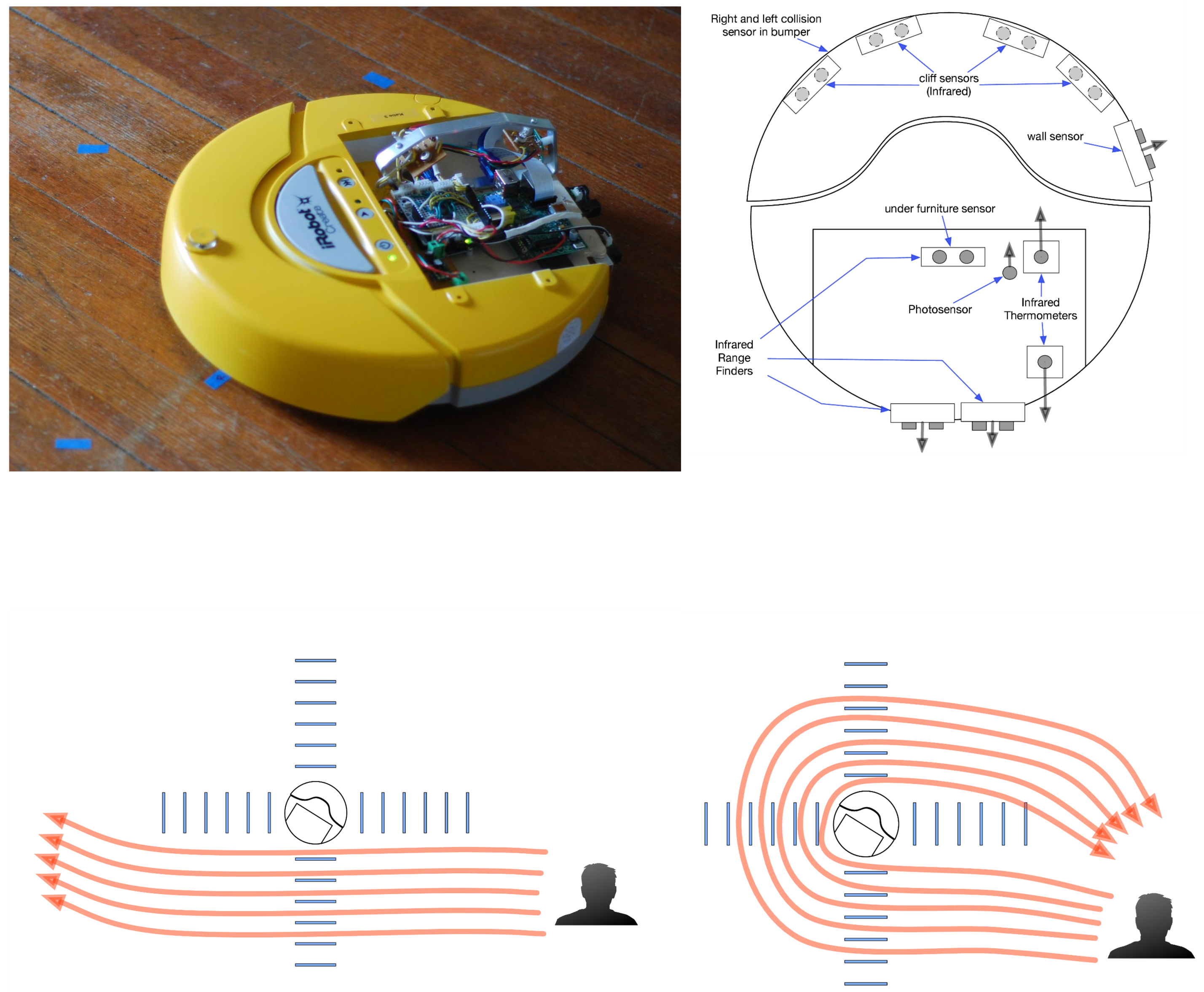

Figure 1. *Top Left – The Katie robot in experimental setup.*
Top Right – the schematic layout of the robot's sensors.
Bottom Left – Diagram of Scenario 1.
Bottom Right – Diagram of Scenario 2

Results

- Robot runs successfully for hours without recharging, records observations every one to two tenths of a second, and uploads all data to a webserver
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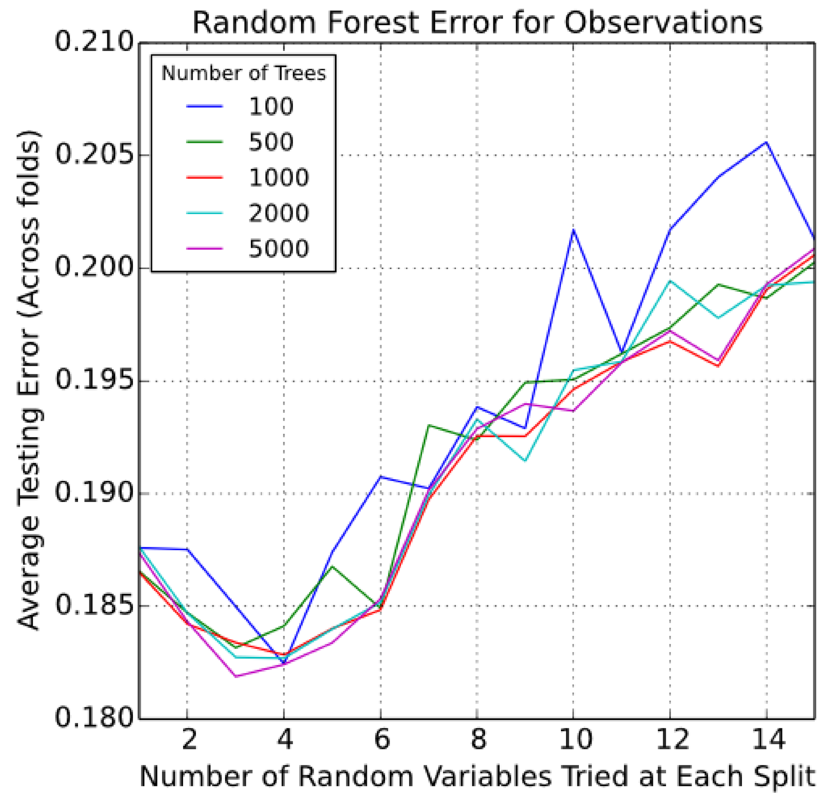
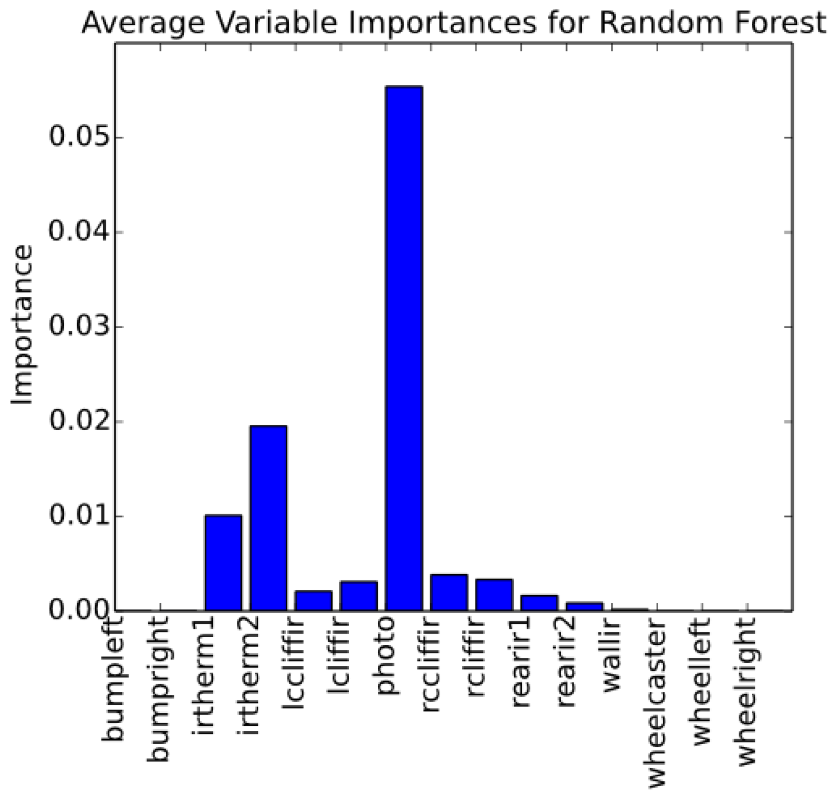
- Classifiers can distinguish well between scenarios. Random Forest has the best performance generally, with an accuracy of about 80% classifying the observations between 3 scenarios, and about 90% between binary classifications of whole experiments, which avoid bias towards experiments with many observations, including a high F1 statistic and Mathew's Correlation Coefficient.

- The most valuable sensors were the photo sensor which detects shadows, the IR thermometers which detect body heat, and the cliff sensors which detect floor vibrations.

- Dividing observations into regular time intervals or adding delayed variables does not significantly change the performance (not shown).

Results (cont.)





Classifier	Observation Error	Experiment Error
Random Forest	0.182 ± .041	0.273 ± .094
SAMME Boosting	0.204 ± .055	0.293 ± .106
Logistic Regression	0.209 ± .065	0.320 ± .086
Trivial	0.209 ± .019	0.667 ± .000
Random	0.586 ± .007	0.664 ±.001

Table 1: Observation and Experiment Classification Errors

Classifier	Accuracy	F1	MCC
R. Forest	0.900 ± .075	0.893 ± .094	0.826 ± .128
SAMME	0.860 ± .077	0.856 ± .092	0.748 ± .139
Log. Reg.	0.880 ± .066	0.862 ± .090	0.789 ± .110
Trivial	0.500 ± 0	0.667 ± .000	N/A
Random	0.519 ± .001	0.673 ± .001	N/A

Table 2: Experiment Binary Classification Statistics on Scenarios 1 and 2

Conclusions

- Distinctions between social behavior are possible with low resolution sensors and simple robotics.

- Simple classifiers can distinguish between simplified social scenarios with high accuracy.

- Further experiments involving more realistic scenarios and more adaptive classifiers are required, and in progress, to determine whether natural social behavior can be distinguished by the Katie robot.

- Interactive mechanisms are required, and in development, to allow the Katie robot to truly navigate a social space, in addition to spatial mechanisms to navigate physical space.