# Project Proposal

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Grounding via Embedded Affordances Utilizing an Android Phone as a Low-Cost Robotics Platform

## Introduction

A fundamental issue within Developmental Robotics and AI is the Symbol Grounding Problem (Harnad 1990). In order to function flexibly and adaptively within a natural environment, an embodied agent or robot must be able to make the connection between concrete instances of objects ‘in the world’ and knowledge ‘in the head‘, its internal symbolic representation. Affordances, introduced by Gibson (1977) and expanded upon by Norman (1988), are those properties of an object that suggest potential for action. Affordances are dependent upon the specific capabilities of the perceiver. This project will explore embedding location and affordance information throughout an environment to enable a robot to find and interact appropriately with objects in the a home environment.

### Target Audience

The target audience for this technology is any individual who would like domestic assistance in the home. This could range from a stay at home parent to a busy executive or elderly couple. Basically anyone who doesn’t care for housework chores or who needs support in the home.

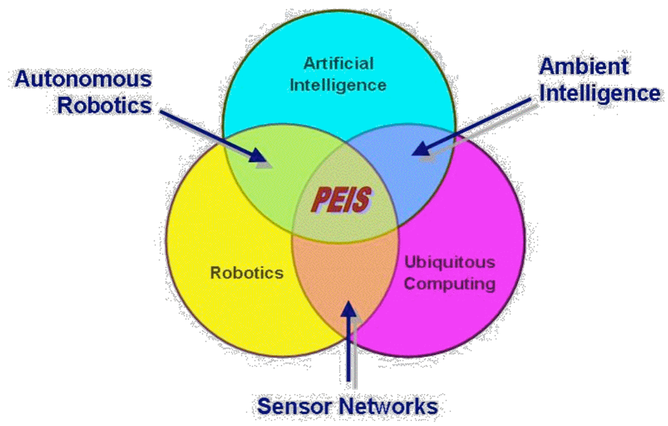
### Need

For individuals employed outside the home and working long hours, household chores are a burden, stealing precious time that could be spent on more meaningful pursuits. Many people simply detest housework. A third group are not able to be independent due to disability and need support to stay in their homes. Any advancements in household automation would be a huge boon to all three of these audiences. In order to evolve from Roomba to Rosie, it will be necessary to develop systems that are capable of associating meaningful information about their physical environment with an internal system representations. Another requirement is ability to couple appropriate actions for specific instances of objects with the behavioral capabilities of a particular robot.

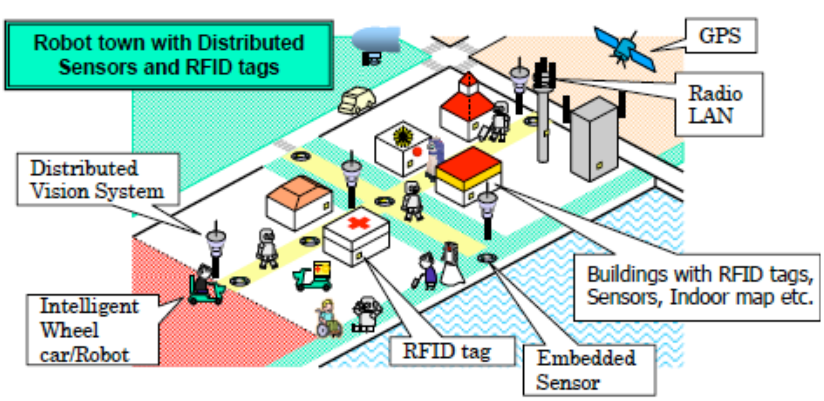
*Getting from Roomba to Rosie will require robots that can make sense of their environment*

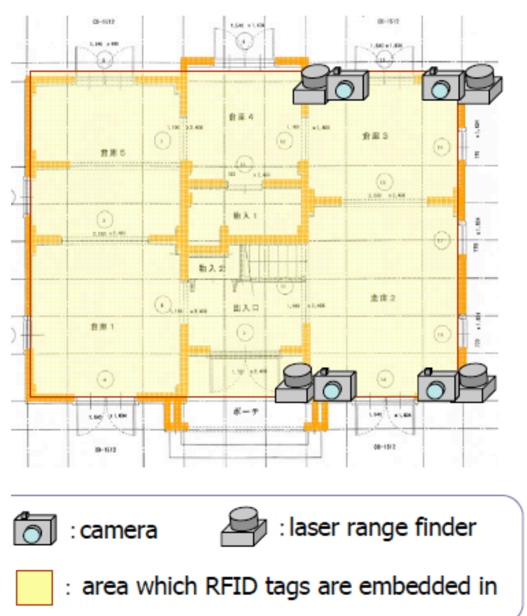
## Related Work

Researchers from the AASS Mobile Robotics Lab at ¨Orebro University in Sweden coined the term Physically Embedded Intelligent Systems-ecology (PEIS-PEIS) to describe an approach that combines aspects of ambient intelligent systems and autonomous robotics to develop assistive service robots. The PEIS-Ecology approach distributes the sensors and system components throughout the environment. Perception and manipulation of objects is augmented by information stored in IC tags and the robots positioning within the environment is supported by external cameras. A variety of networked subsystems and devices cooperate to perform tasks.




Researchers at Kyushu University in in Fukuoka City, Japan have developed the Robot Town Platform, an information-based structured environment designed to support a robot by providing it will real-time information about its location and the environment. The platform is implemented in a city block outfitted with cameras, laser range finders and RFID tags which are distributed throughout the environment.




Robot Town includes a 5 room home in which location information is supplied to the system using ceiling mounted cameras and laser range finders. GPS requires a clear line of sight so will not function properly indoors.

### Idea Filter

*If a 2-year-old child cannot solve your task then your project idea is probably too complicated.*

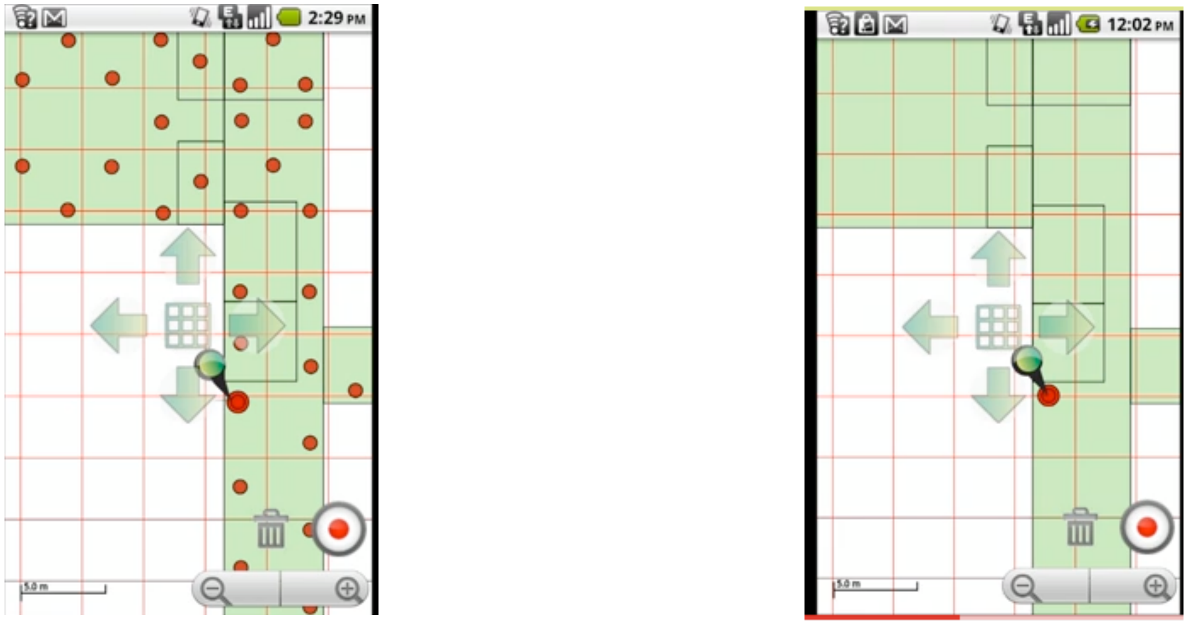
For this project I will be limiting the scope to simulate local navigation within a home environment using simple commands and expecting the 'robot' to connect its behavior repertoire with an object based on the affordances associated with it. An example of a command sequence would be: Go to Kitchen, find coffee pot, show coffee pot, what do I do with coffee pot?.

## Approach

Data tags will be embedded throughout the environment to encode information about the physical layout and properties of static elements in the environment, such as rooms doors, windows, cabinets and light switches. Objects of interest (defined in this project as objects that we would like the robot to interact with) will also be tagged with location properties and affordance information. The application for the system proposed here is an in-home service robot. Cues in the operating environment will supply information about the physical location, objects and available object interactions. The project will build a framework on which the robot can build a subjective representation based on experience. This initial knowledge base is intended to be used as part of a training regimen where the tagged items in the environment serve to ground concepts and knowledge 'in the world'. Additional learning algorithms could be used to generalize the data to similar contexts. The learning algorithms for generalization are be outside the scope of the project are suggested as future work.

GPS is not functional indoors and the laser scanning technology that has been used in other robotic systems is extremely expensive. Indoor positioning technology that utilizes environmental RF (radio frequency) information including WLAN, GSM, electric compass orientation, and Bluetooth, is an attractive option for indoor positioning using using an Android phone. Using this technique a radio map is developed for a set of marker points (a training phase). During operation the position of the device (in our case the robot) is determined by matching the current RF sample with the stored map. Gecko, a system being developed in Sweden, will be available to developers free of charge. Unfortunately after signing up to participate, It was discovered that the API used to incorporate the fingerprint information into custom applications has not been released yet.


*Gecko uses Google Earth to establish location data with superimposed floor-plan.*



*Gecko map during training phase showing location fingerprints (left). Gecko map showing current location (right).*

The Android platform with built-in microphone, bluetooth, wireless, camera, GPS, and accelerometer has many features that would be useful for sensing functions in a robot. In fact there are interfaces to robotic platforms detailed on cellbots.com.

RFID readers for Android are just around the corner. The latest release of the Android OS, Gingerbread, is not yet widely available, but has built-in support for Near Field Communications (NFC). In systems composed of hardware and software using the Android NFC API, apps will be able to respond to NFC tags embedded in stickers, posters, and other devices.

This will be a proof of concept exercise because, as noted above, the technology I had hoped to use for this project, Gecko and RFID for Android, is not quite ready for prime time. All proposed aspects of this system are technically feasible and should be readily available within the year. The exercise of executing this project will provide a foundation for a full implementation at a later date.

I will utilize canned data to simulate location fingerprint data in the test system. QR Code barcode tags will be used to simulate RFID tags and also to store location data. These data contained in these markers will be used build out the location and object property database needed to build out the model of the environment during a training phase and to provide data required during the operation phase.

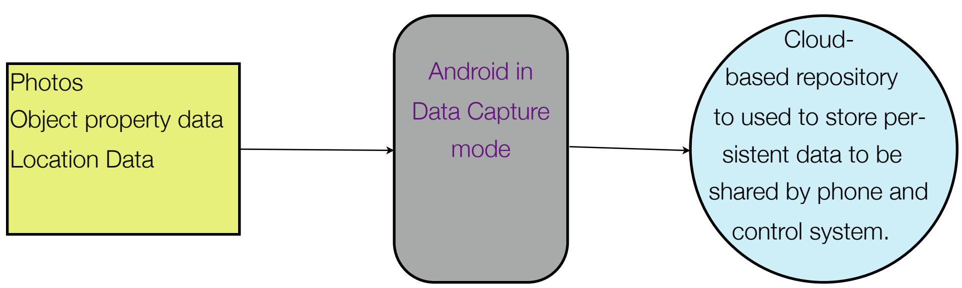
*QR Code Barcodes will be used to encode information*

Given the project timeframe, it is not practical to attempt native Android OS development in Java using the Android SDK. Google App Inventor will be used to create most data collection software on the phone. App Inventor is a drag and drop web-based interface that can be used to create applications for Android. It is quite flexible, but does not support the entire Android API. For example, it is not possible to program the phone to automatically take a photo without user intervention. If deemed necessary, App Inventor code will be supplemented by Python or Ruby applications developed with Scripting Layer for Android (SL4A). SL4A is an open source project that provides the capability to create interactive scripts that have access to more Android API functionality than does App Inventor.

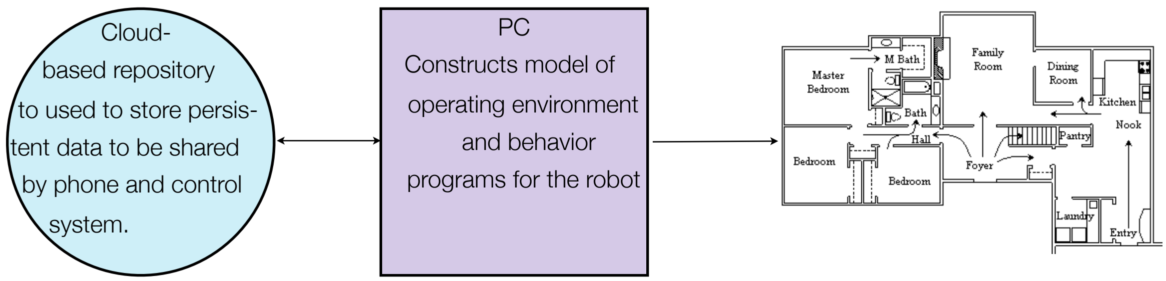
The data collected will be saved to a cloud-based data repository using the App Inventor TinyWebDB component.  To train the robot information embedded in the environment via simulated RFID tags will be associated with data acquired through the other senses (location, sound, image). I will utilize a 'Wizard of Oz" protocol to test the whether the robot is able to function in the tagged environment. Because I do not have access to a robot, a human will play the role of the robot's motor control system and will respond to commands sent to it during Run mode. The Android and my Mac will play the parts of the senses and cognitive systems.

### Modes of Operation

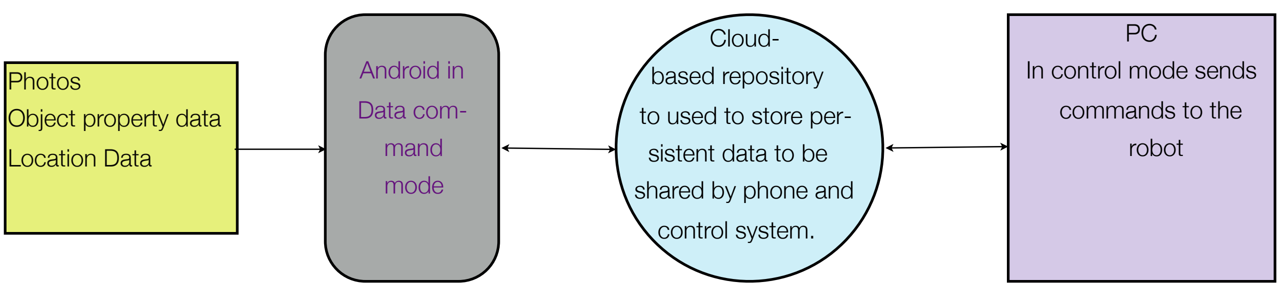
Training Mode - During the training mode the 'robot' (Android phone) will take readings of the tags containing location data and object property data. This data will be sent to a cloud-based data repository using the TinyWebDB component.



Construction Mode - The construction mode will be used to build out a model of the robot's environment using data collected during training mode. Data points collected will be stored with a map of the robot's operating environment.




Command Mode - The command mode will be the standard operating mode for the system. In command mode the system will respond to commands issued from the control system and utilize information encoded in the environment through the data tags. In a 'real' system, the robot would be able to detect the tags without user guidance, as RFID would be used. This system will need to simulate location of tags through the use of barcoded tags. Communication between the control system and the robot will be through the common data repository.




## Software libraries

This project will use a combination of Google App Inventor blocks, Google App Engine libraries, and open source Scripting Layer for Android (SL4A) for Python or Ruby if necessary. The control software will be developed in Python using the web2py web framework.

### Schedule

| Date | Task |
|---|---|
| Week 0 | Perform feasibility assessment of various libraries and indoor local positioning technology. |
| Week 1 | Develop data collection module for Android, design data structures, create database, create barcode data tags |
| Week 2 | Develop construction mode web application, setup database, perform data collection. |
| Week 3 | Develop command application (web2py) |
| Week 4 | Develop command response application for Android |
| Week 5 | Perform system test and begin project writeup |
| Week 6 | Final writeup |

### Equipment

Equipment the equipment used on this project will include an Android HTC Desire phone with version 2.2 of the Android OS (necessary to enable program storage on the SD card), a networked personal computer, and printer to produce barcodes.

## Evaluation Methodology

### Test Plan

The test protocol will consist of a training mode, construction mode, and a command mode, as described above.

The the training phase will encode location data for a residential home using location data based on the measured floor-plan of the house. Static features such as doorways, light switches, cabinets, and drawers will tagged for reference as well. A number of common household objects will be tagged with properties relevant to the robot's capabilities. The data capture application will acquire barcode data and also send sensory data to be associated with the barcode reading. The text data will be stored in the common repository. Due to technical limitations with App Inventor. Images will be manually transferred to the system.

The construction mode will be used to build the model of the robot's operating by associating the data collected through data tags with a known floor-plan and knowledge base containing robot behaviors.

The operating mode will be used to demonstrate the system capabilities through a command/response protocol with between the control system and the 'robot' (android phone). The robot will be expected to respond to a series of commands by sending back appropriate responses to the control system via the common repository. This project will be considered a success if the robot is able to successfully navigate to the commanded location, find the object commanded (based on proximity), send back a picture of the object and describe correct behaviors based on object properties.

### Experience - about me

I work full time as a User Experience Architect for a large financial services company and am currently enrolled in the HCI Online Masters program at Iowa State. My areas of interest are usability, design, and information architecture. Prior to my work in UX, I worked for many years as a software engineer. Though I no longer code for a living, I have attempted to keep my skills intact by taking the occasional course for continuing education. Professionally I have coded in Fortran, C, C++, and C#. My coursework has added Java and Python to the mix. I do not have any direct experience with vision systems or image processing. I have worked with numerous API's over the years and am comfortable digging in to figure stuff out. I have worked in with barcode readers, and smart card systems, CAD systems, and as a database architect, though all of that was eons ago.

I believe this project will succeed because I have been around the block enough times to know how to combine components to create a practical solution to problems. I have researched the tools through a preliminary feasibility trial, so am fairly confident I can implement my solution as outlined in this paper.

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