From Industry to Home: Rapid Development of a ZigBee-Based Indoor Positioning System for Use in Private Residences

Seth Tumlin

Internet of Things (IoT):

The recent trend of connecting anything and everything to the internet in order to automate or simplify tasks.

Smart Home Technology:

IoT devices and networks meant for use in the home.

Location Based Service (LBS):

An algorithm that performs tasks based on the user's location.

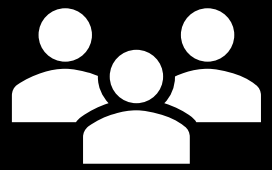
Indoor Positioning System (IPS):

A system, much like a GPS, used to determine the position of a target inside of a building.

Smart Home Technology

- Conserve energy -Chen et al.
- Allow elderly/disabled to live independently –Rizvi et al.
- Increase home security -Rehman et al.
- Prevent fires and other hazards –Hsu et al.
- And more

The Problem



More than 1 in 3 smart homeowners believe the technology is not worth the price.

-Sanguinetti et al.

The Problem

"[Smart home technology] is unsatisfactory unless it offers scope for interaction."

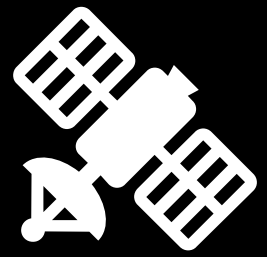
-Darby

Location Based Services

"[LBSs] enable location scenario control, making home appliance control easier and enhancing the power utilization efficiency. "

-Cheng et al.

Location Based Services



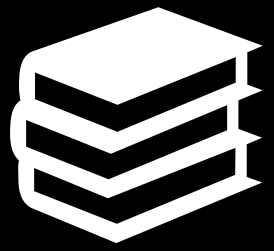
"[GPS] operation in indoor or obstructed environments is infeasible, and, instead, alternative systems have to be adopted."

-Dardari et al.

IPSs

- Retail –Takahashi
- Industrial –Razak et al.
- Agriculture –Lepej et al.
- Single nursing home rooms –Pourhomayoun et al.
- Small apartments –Vlasenko et al.

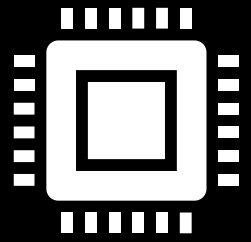
The Gap



"There are still considerable gaps in the research literature."

-Gram Hassen & Darby

The Gap

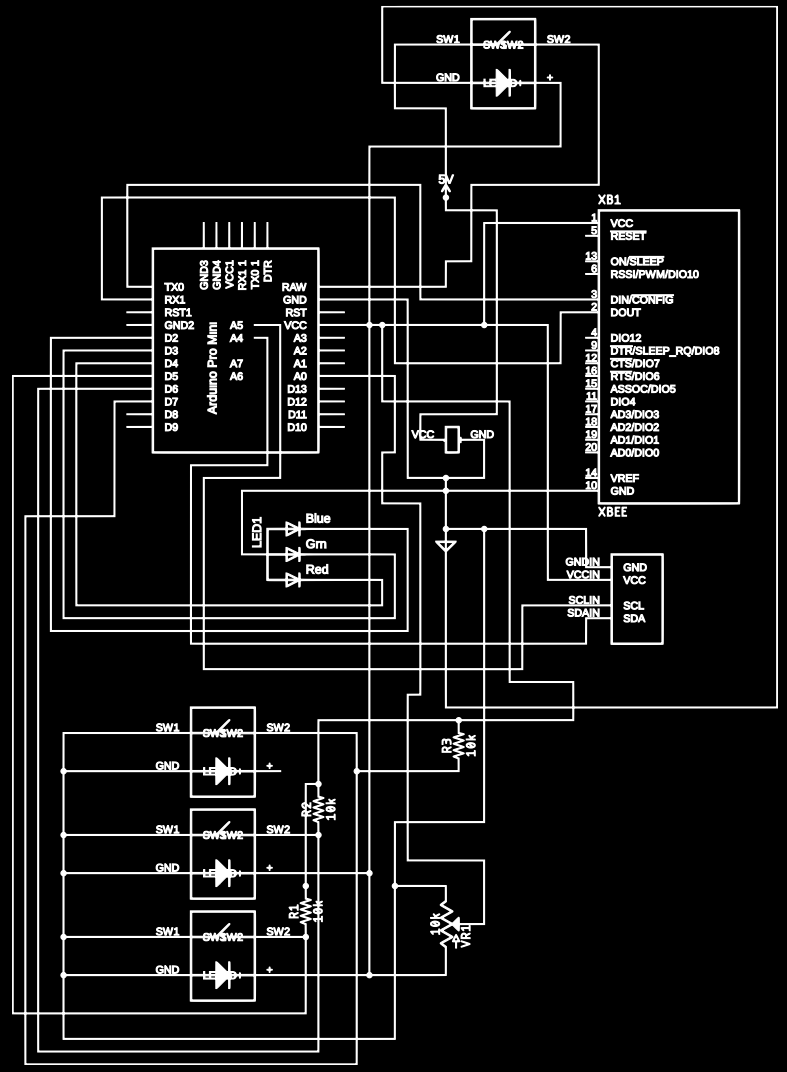


"in future evaluative studies of smart homes – sorely needed – we suggest the inclusion of questions about how meanings of the home might change along with new technologies."

-Gram Hassen & Darby

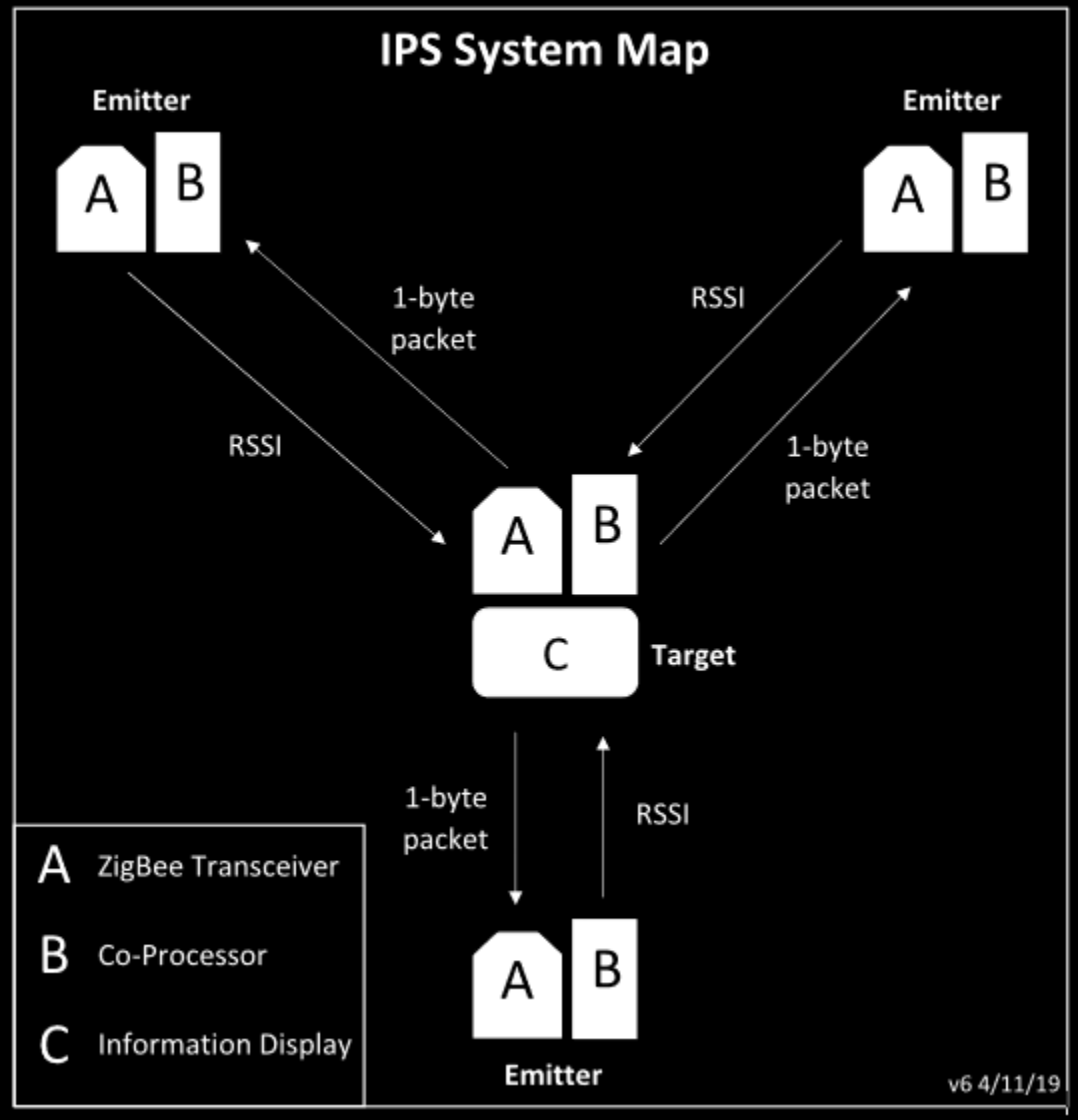
Design & Construction

The Prototype

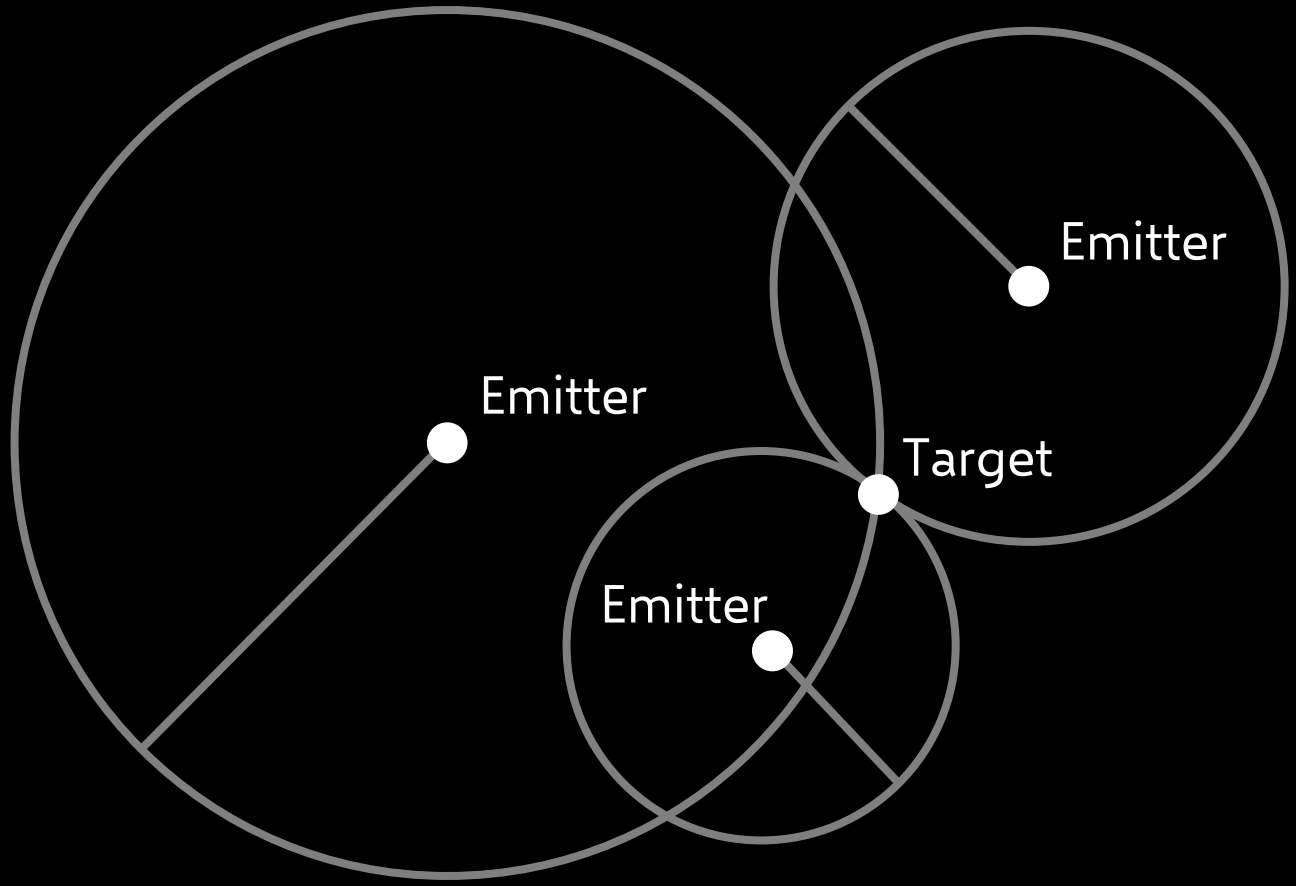


Design & Construction

Theory of Operation



Triangulation



Ethics

Letter of Authorization

Homeowner at specified address,

I am seeking your authorization to conduct a research study at your home (at the specified address) that is designed to assess the accuracy and precision of an indoor positioning system.

I would like to collect various location data throughout the house using GPS and an indoor positioning system. This study is a requirement to compete the AP Research exam. Participation in this study is entirely voluntary. You are free to withdraw from the study at any time without fear of penalty. The only requirements are that the house must be empty at the time of testing, and that all Wi-Fi signals and microwave ovens are turned off. The latitude/longitude data from the GPS will be truncated at the decimal, making it impossible to discern the location of the home. All other identifying information (address, etc.) will never be recorded other than this form and will not appear in the final paper. The different homes will be recorded as trial 1, trial 2, etc.

The risks involved with participating in this study should be no more than the time needed to conduct the test, which I estimate to be about one to one half of an hour.

If you have any questions or concerns about participation in this study, you may contact me.

Respectfully,

I authorize the researcher to conduct a research study at the specified address concerning the effectiveness of accuracy and precision of an indoor positioning system for up to one half of an hour. I understand that he will be collecting location data throughout my house (at specified address).

_____

_____

_____

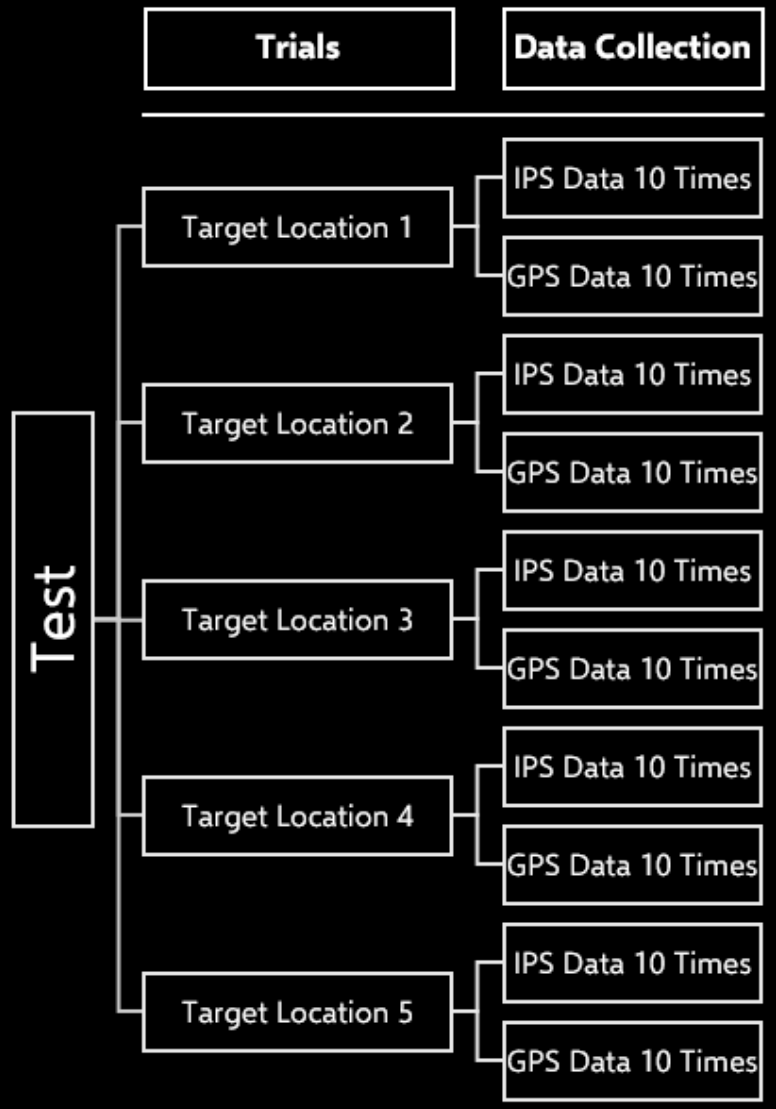
_____

Address of Home

_____ _____

Homeowner's Signature Date

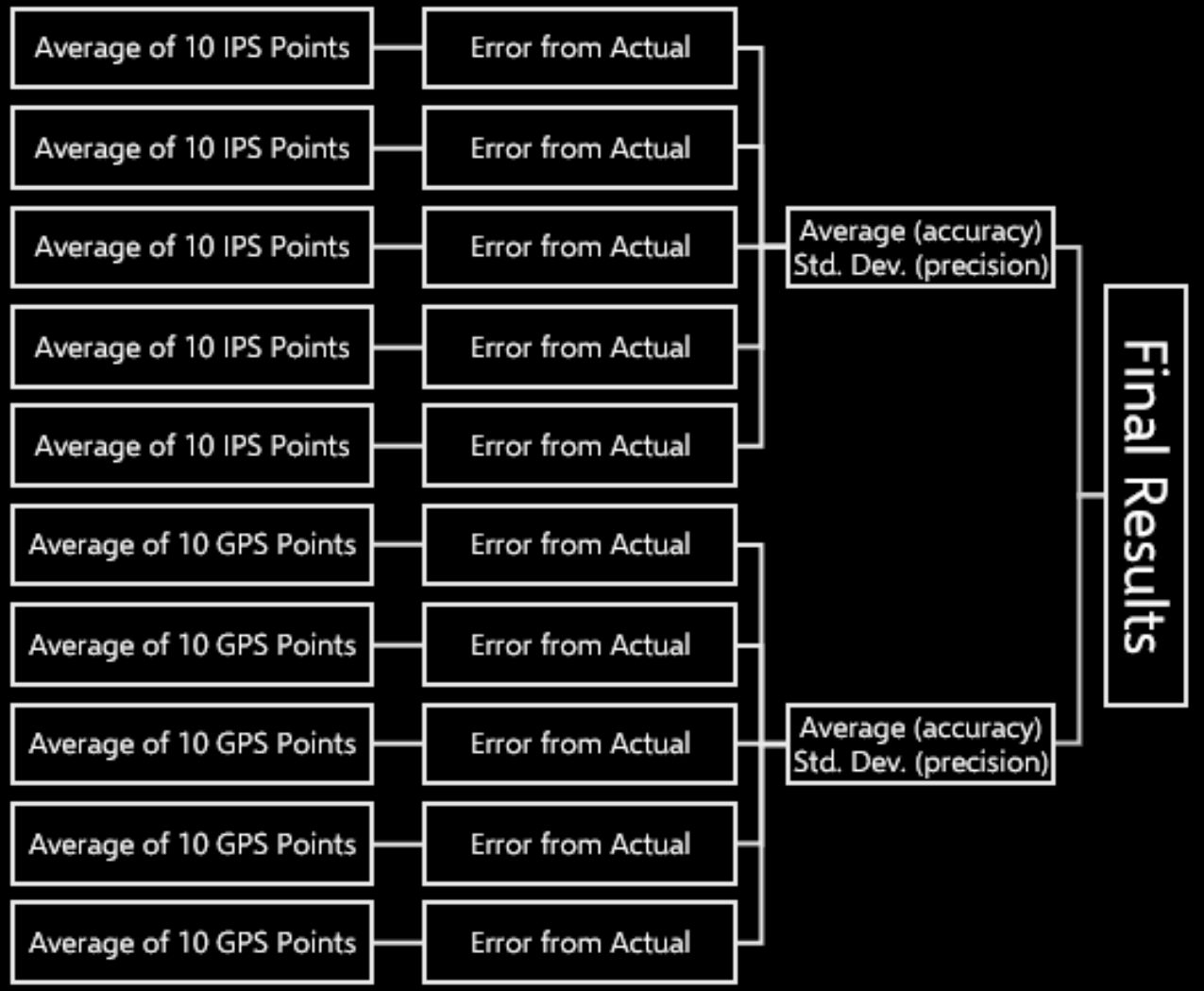
Running the Test



Data Analysis

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

Data Analysis



Data

RMSE Calculations			
	Actual Location	IPS Error Radius (in.)	GPS Error Radius (in.)
Trial 1	(143, 44)	3.16	95.34
Trial 2	(92, 93)	8.60	8.06
Trial 3	(174, 52)	5.66	45.35
Trial 4	(10, 190)	10.20	25.61
Trial 5	(37, 201)	6.40	18.68

	IPS	GPS
Mean	6.80	38.61
Std. Dev.	2.72	34.51

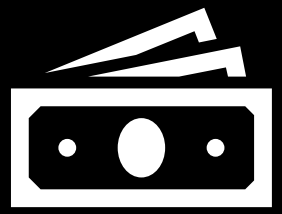
Discussion

The IPS was 5.7 times more accurate than the GPS in the test.

Discussion

The IPS was 12 times more precise than the GPS in the test.

Limitations



"Most future commercially available systems will likely have considerably more capital – the likes of which are not available for this study – dedicated to research and development."

-My research paper

Future Implications

- Bringing IPSs to smart homes
- Other technologies being implemented in the home
- Implementation of IPSs and other technologies into new areas beyond the home.

Future Directions

- Replication of this study
- Documentation of development process
- Other industry technologies in smart homes
- Other IPS technologies in homes
- Ethics of IPSs

Citations

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