



*This presentation includes several videos. Please use the powerpoint version when possible. Available at
<http://patpannuto.com/talks.html>*



PolyPoint and the First Steps Towards Ubiquitous Localization

Pat Pannuto

In collaboration with Benjamin Kempke, Bradford Campbell,
Ye-Sheng Kuo, William Huang, Joshua Adkins, and Prabal Dutta

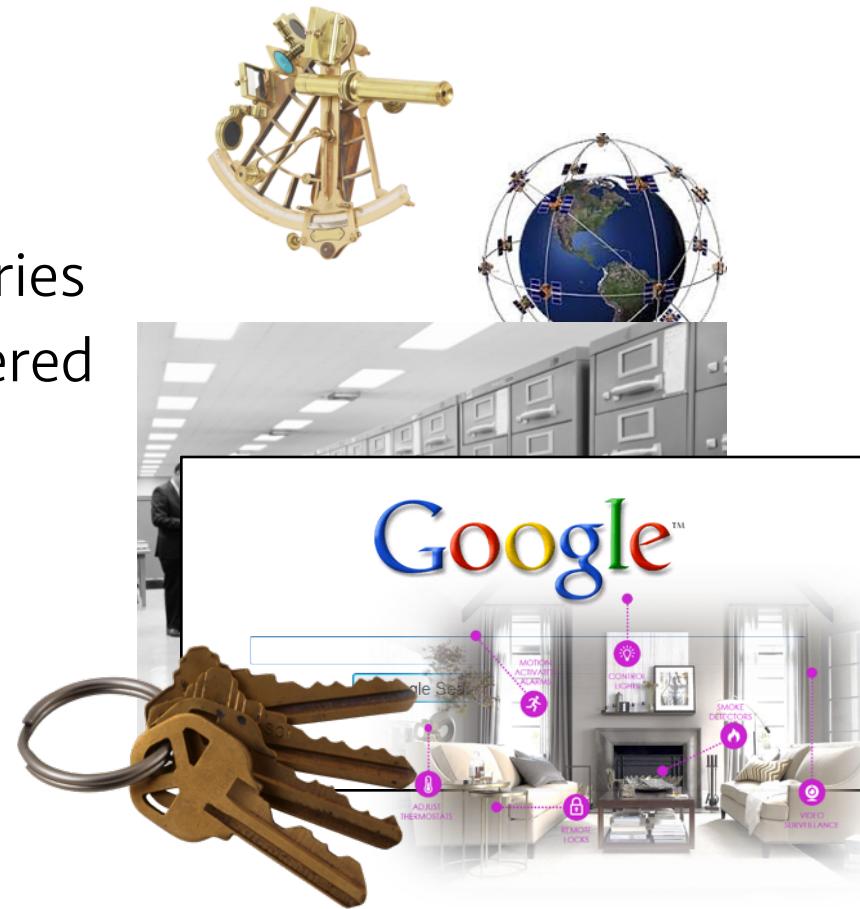
Student Summit on Mobility, Systems, and Networking

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Localization technology is on the cusp of a new revolution

- Reliable sea-faring invited the “Age of Discovery”
- GPS built and reinvented industries
- Digitization of information ushered in the “Information Age”
 - Search vs File
- In the next 20 years, ubiquitous localization is nigh
 - Search vs File of *physical things*

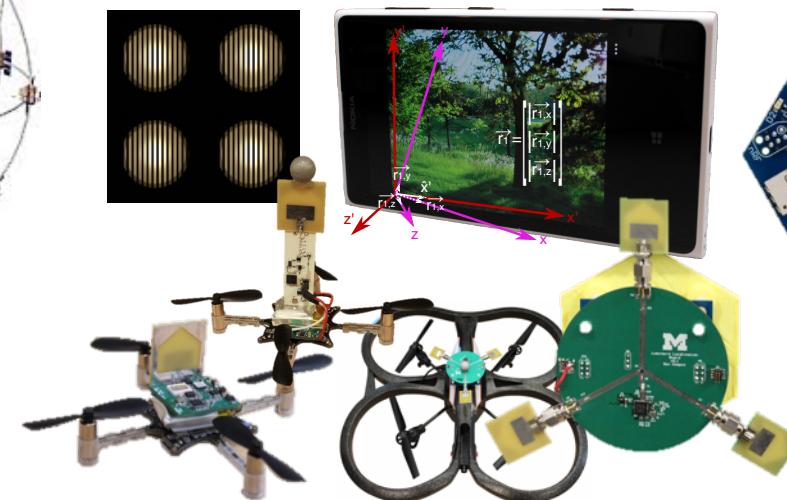


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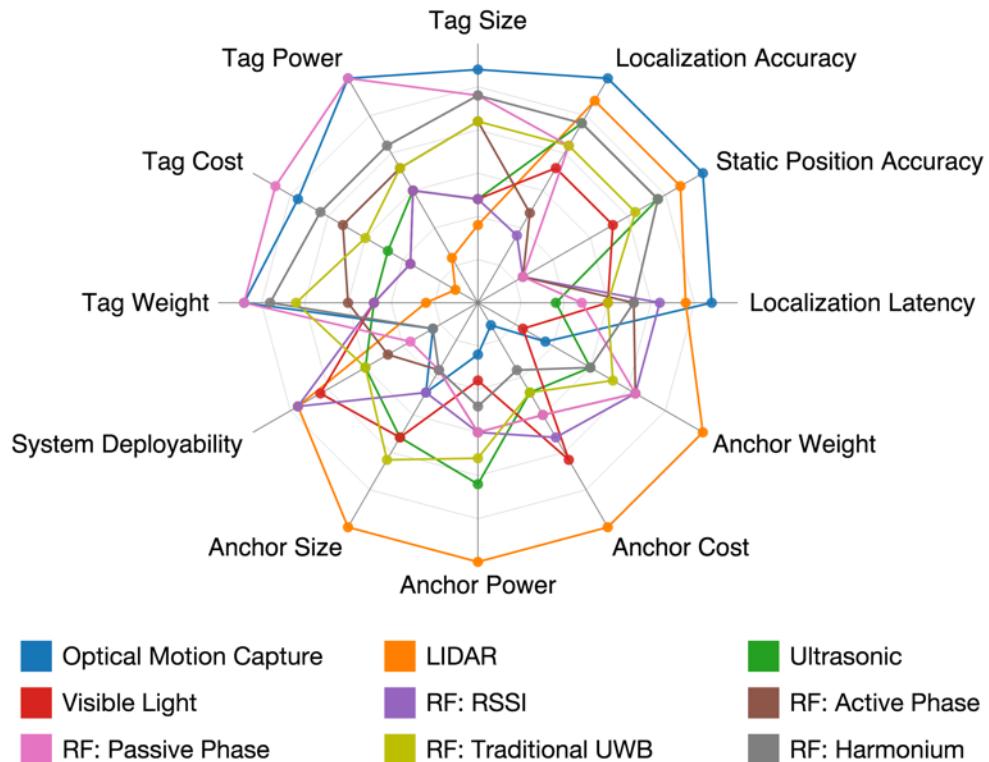


- That we “solved” in the 1970s
- That we are still solving today

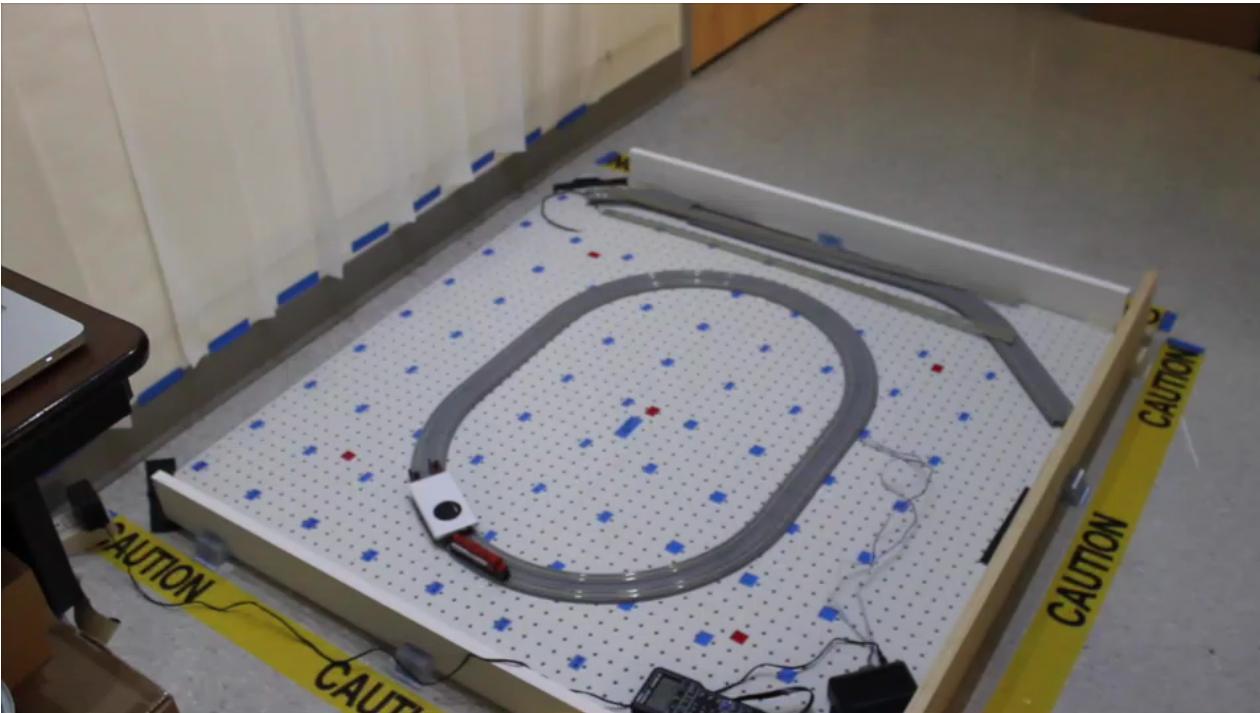


Localization technologies present an immense tradeoff space

- Here are 12 dimensions
 - Covering 9 technologies
 - Each have several implementations
- Is there a universal “right answer”?



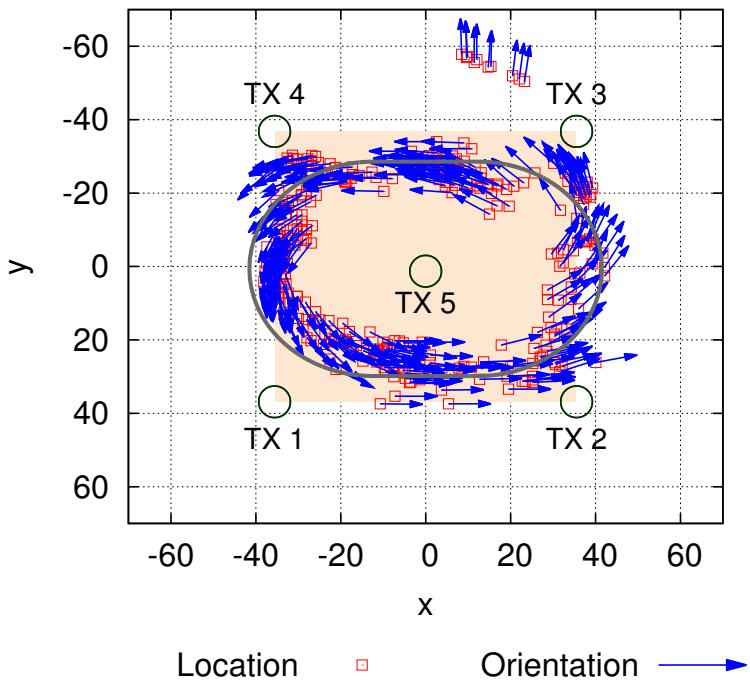
Luxapose: Astral navigation with smart phones and smart lights



Luxapose: Indoor Positioning with Mobile Phones and Visible Light (MobiCom'14)

Ye-Sheng Kuo, Pat Pannuto, Ko-Jen Hsiao, and Prabal Dutta

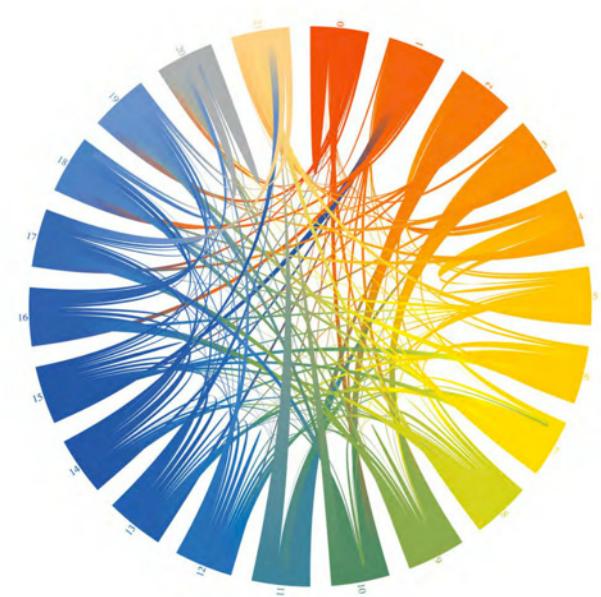
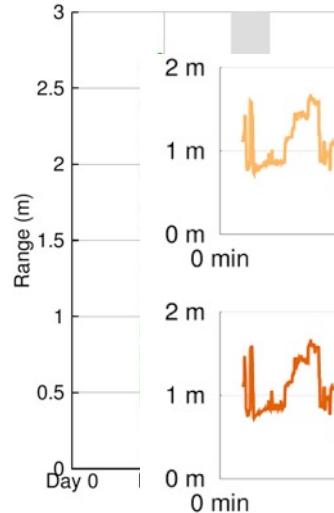
Luxapose enables high-fidelity indoor localization with impending infrastructure



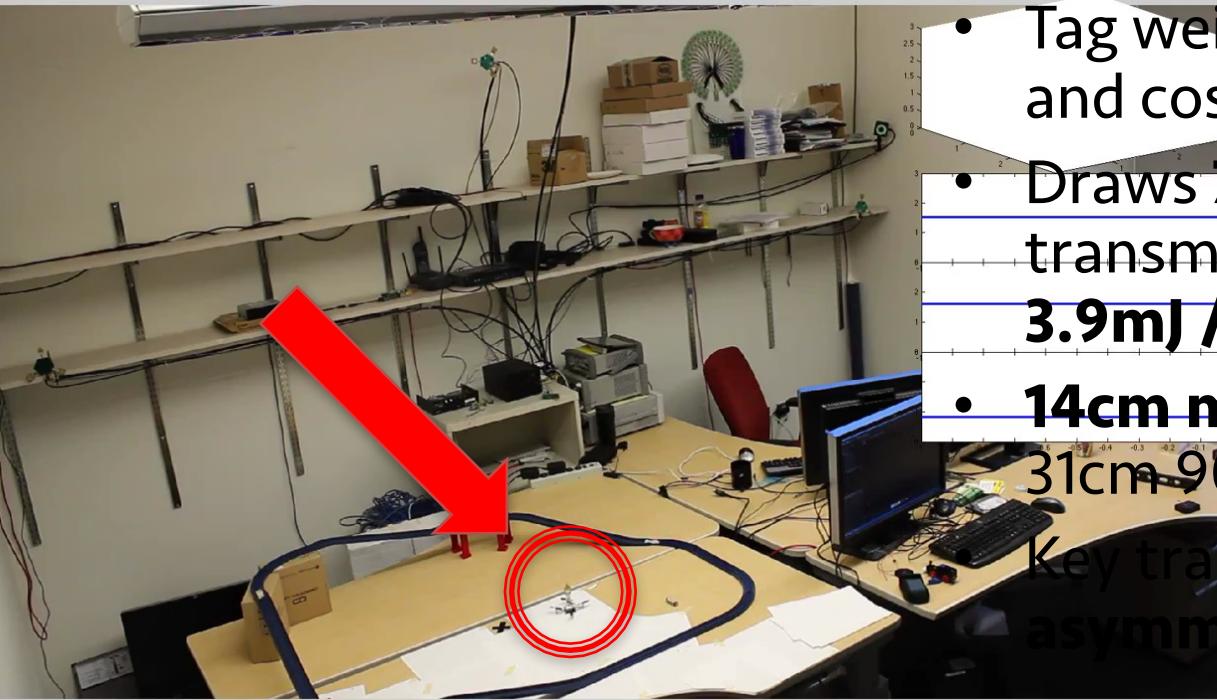
- Decimeter-level accuracy
- Unmodified smartphones
- Trivially modified LED lights

Opo: Forgoing *absolute* location for high fidelity *relative* location

- Application
 - Human Interaction Tracking
 - Key Tradeoffs
 - Ranging Accuracy
 - Duration Accuracy
 - Usability
 - Opo
 - 5 cm accuracy, 2 s minimum interaction, 93 hour battery life



Harmonium: Enabling high-speed, high-fidelity tracking of fast-moving objects with UWB



- Tag weighs **3g** and costs **~\$4.50**
- Draws **75mW** transmitting, **3.9mJ / fix**
- **14cm median** 31cm 90%ile
Key tradeoff is **asymmetry**

A graph showing a distribution curve with a peak at 14cm and a long tail extending to 31cm.

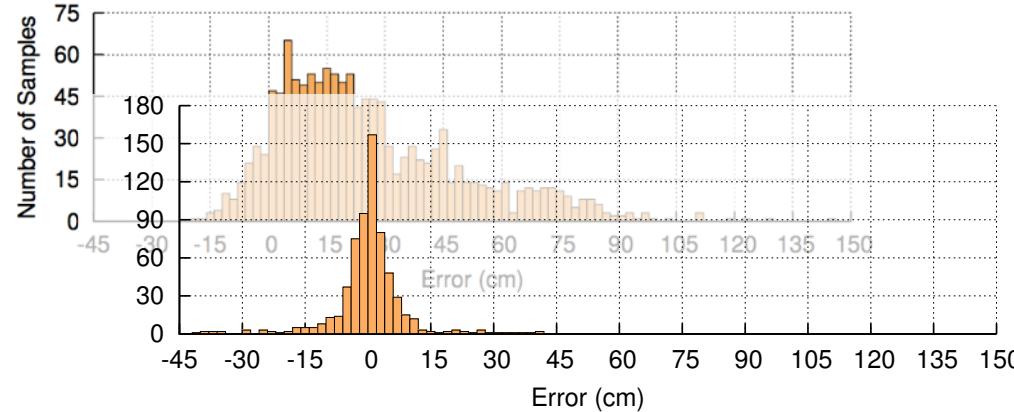
Harmonia: Wideband Spreading for Accurate Indoor RF Localization (HotWireless'14)

Harmonium: Asymmetric, Active UWB for High-Quality Indoor Localization (To Appear: IPSN'16)

Benjamin Kempke, Pat Pannuto, and Prabal Dutta

PolyPoint is a low-cost, high-fidelity indoor localization system

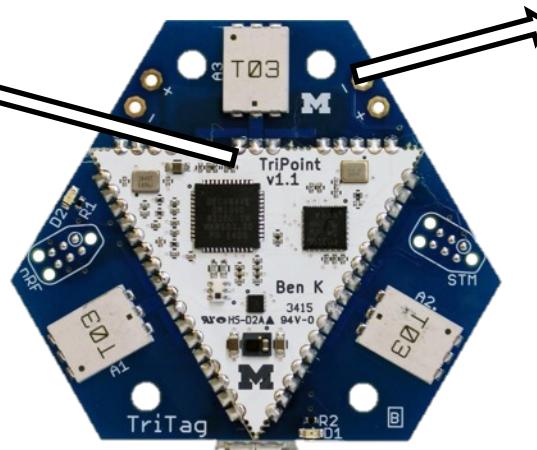
- A high-accuracy, *stateless* RF localization system
 - Fixed, known-location anchors
 - Tags range to each anchor
- Key to accuracy is *diversity*
 - Frequency
 - Spatial
 - Polarization
- 2015 Microsoft Indoor Localization Competition
 - Best-in-class 2D *median* accuracy (9cm)
 - 3rd Place 2D *average* accuracy (60cm)



PolyPoint Today: Providing localization as a drop-in, modular primitive

TriPoint

- Drop-in localization module
- Towards “where-am-I” as an I²C command



TriTag

- Carrier board
- Adds BLE for offloading position information

Looking 20 years into the future

- Today's digital things have a few fundamental primitives
 - "Sense of Self"
 - "Sense of Time"
- Tomorrow's things will include a "Sense of where"
- The long tail is full of interesting research
 - There are devices for whom a sense of time is difficult today
 - There will be those for whom location is difficult tomorrow
 - Drives a lot of unique and novel systems and technology solutions

For More Information...



- <http://lab11.eecs.umich.edu>
- <http://github.com/lab11>
 - lab11/vlc-localization [luxapose]
 - lab11/opo
 - lab11/fast-square [harmonium]
 - lab11/polypoint
- <http://patpannuto.com>

