RF Wireless Positioning for the Robot Chess Game

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Agenda

- Introduction
- Distance “Ranging” Methods
  - And why some of the things we have spoken about before in class won’t work
- Sources of error in Distance Estimation
  - And what to do about it
- Ultra-Wide Band (UWB) Systems
- Available Technologies and Products
- Where we go from here
Introduction

Our **chess game** requires a system for estimating the position of the robotic chess pieces in real time, with **very high accuracy**.

- Squares on the chess board may be a foot or two square
- Need real-time feedback mechanism for pulsing motors
- Precision must be on the order of inches!
Other Positioning Requirements

- Low Power
- Small Footprint
- Compatible with Arduino Microcontroller
- Low Cost

These requirement led me to investigate RF solutions

- An RF solution might co-habitate with data transfer mechanism between robots and controllers
Triangulation

- All wireless positioning methods use Euclidean geometry and the Pythagorean theorem.
- Some methods use anchor nodes with known fixed locations.
- Others use Self-Organized Maps.
- In all cases, precise 3D positioning requires very precise distance measurements between nodes.
Distance estimation methods using RF

- Received signal strength
  - Received signal power diminishes with the square of the distance
  - Easy to implement, but...
  - Inaccuracy due to interference and multipath effects
  - Needs “fingerprinting” for indoor use
  - Available products usually don’t provide RSS measurements with enough resolution
Distance estimation methods using RF

- **Time of Flight**
  - Distance between nodes calculated from the arrival time of an electromagnetic pulse
  - TOA, TDOA
  - Methods exist for situations *without synchronized clocks*
  - Can be built into the MAC layer
  - Used in GPS, mobile phone positioning
  - The **best** method when used with UWB/Spread Spectrum radio systems
Noise Effects
Multipath Effects

- Received multipath signals
- With 50 MHz bandwidth

- Received multipath signals
- With 25 MHz bandwidth
Available Technologies and Products

- Zigbee, Bluetooth, WIFI?
  - All variations of different IEEE 802.11 or 802.15 protocols
  - Clocks in the range of 1 Mhz to 25 Mhz

- The literature all seems to be in agreement that these technologies cannot achieve precision less than a few meters!
Characteristics needed for high distance estimation resolution

- **High** clock rate
  - Higher resolution for TOF == higher distance estimation resolution

- **Wide** transmitted signal bandwidth
  - Eliminates the effects of *noise* on the TOF measurement

- Immunity from multipath effects?
Spread Spectrum

- Digital data transmission technique
- RF signal has much greater bandwidth than the minimum necessary
- Uses a high bit-rate pseudo-random “chip” code
- Very low spectral power density
- Military applications
- CDMA
- **Uniquely immune to multipath effects**
- UWB Bandwidth greater than 500 MHz

- Hedy Lamarr,
  - Inventor of Spread Spectrum
Spread Spectrum

(a) Carrier frequency
BPSK modulator
BPSK modulator
PA

Data
Spreading code

(b) Data
Demodulator
Correlator
LPF
BPF2
BPF1
RF amp

Local oscillator
Phase control
Spreading code
Spread Spectrum

1) Data
2) Code
3) Spread signal
4) Despread signal
5) Demod. data
UWB Wireless Sensor Specs

IEEE 802.15.4a
- Same MAC layer as 802.11.3 (Zigbee), low power, data rate
- UWB Spread Spectrum PHY
- Commercial failure so far, but new company introducing inexpensive chipset next year
- Designed with positioning in mind

IEEE 802.15.3a
- Designed for high data rate WPAN
- Also UWB PHY
- Abandoned by IEEE, but adopted as ECMA 368 and WiMedia
- Used in commercial products
Where to from here....

- WiMedia seems to be the most promising technology available immediately
  - Chipsets available
  - Some evaluation boards available

- The Decawave IEEE 802.15.3a chipset and evaluation boards will come available next year

- FPGA based UWB radios?