Augmented Reality Universal Controller and Identifier (ARUCI)

Group 40

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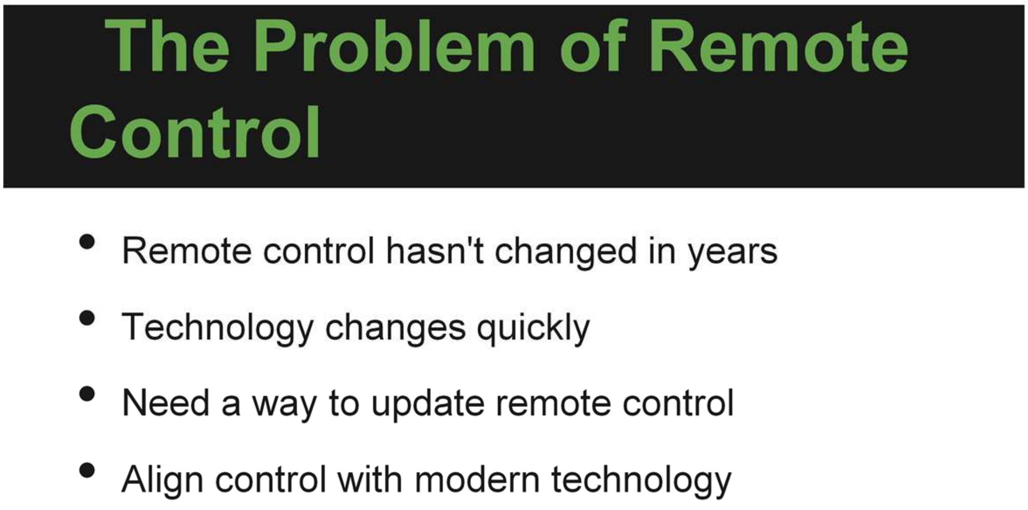
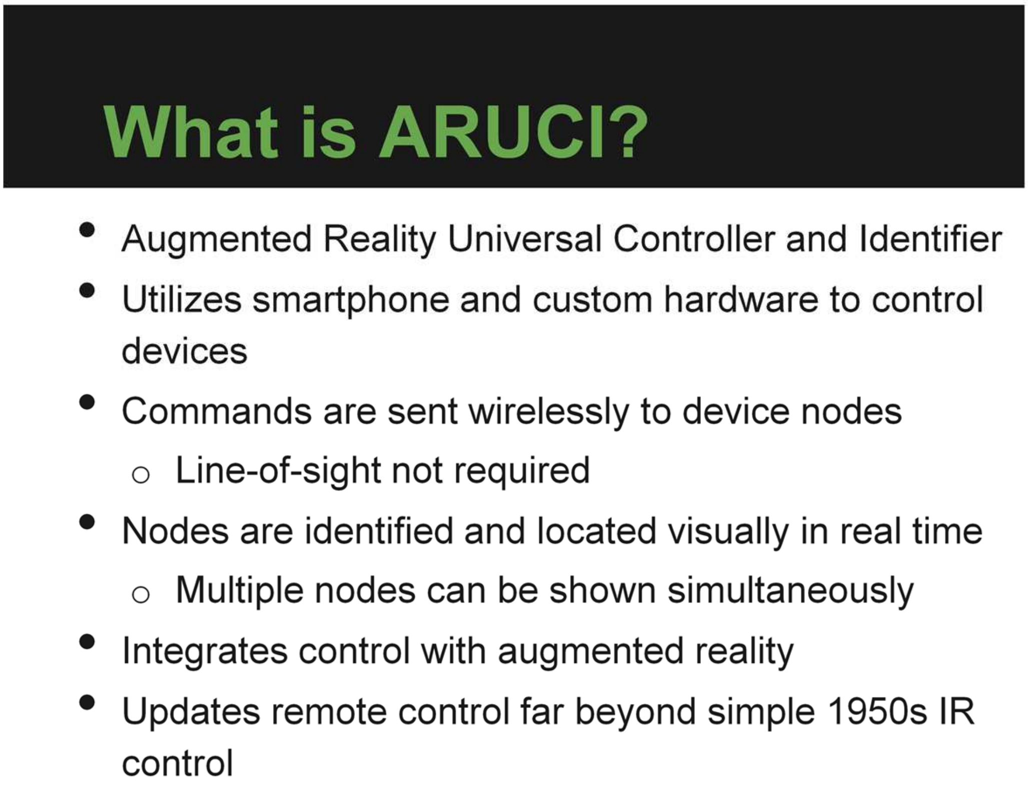
Introduce Presenters, ARUCI, Project Members, Consultant and Group

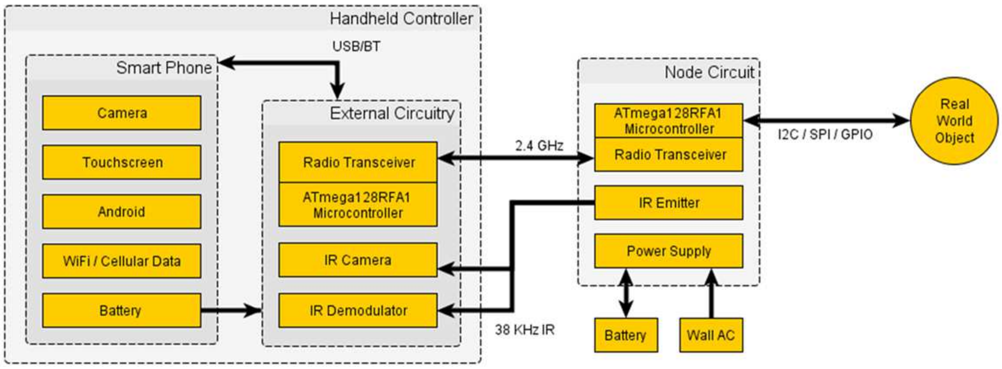


- When looking at remote control, the paradigm has stayed the same since the advent of the technology. However, in today’s market, technology changes quickly. Between televisions and smart phones, and everything integrating with the internet, it would seemingly make sense to upgrade every aspect of our lives to utilize these new technologies. However, remote control has stayed the same, and therefore, this gap between antiquated control and the technology of devices must be fixed.



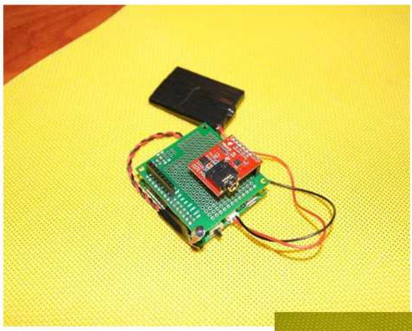
- The Augmented Reality Universal Controller and Identifier is an entire system that allows for the control of electronic devices using a smartphone. Commands and data are sent wirelessly between electronic nodes and a smartphone. The nodes are located and identified in real time, and displayed on an interactive augmented reality overlay. This updates the notion of control far beyond that of standard infrared communication and brings it to present day levels.

ARUCI System



The ARUCI system consists of a circuit attached to the back of a smartphone, and many node circuits. All circuits are capable of communicating wirelessly via a radio transceiver. The nodes are capable of emitting IR signals. The phone-attached circuit can detect the location of the IR emission, and decode the data that is encoded in the IR emission. The phone-attached circuit also communicates to the smartphone via USB or Bluetooth.

Each node also has a flexible application circuit that actually performs a physical task, and configurable power supplies so we can choose between rechargable batteries or wall power.



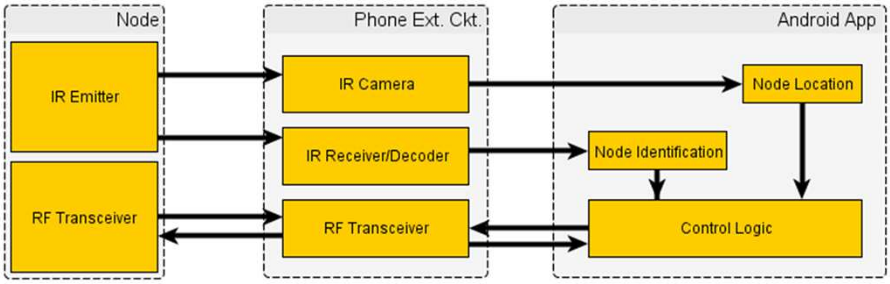
The ARUCI System in Three Parts

A custom designed 3D printed case holds the phone-attached circuit to the smartphone. The case exposes the cameras and IR sensor.

The phone battery is modified with copper tape so the circuit can draw power from it with spring loaded contacts.

The node pictured here shows the FM radio node while being battery powered. The application board bridges the FM radio module and the node circuit.

ARUCI Communication



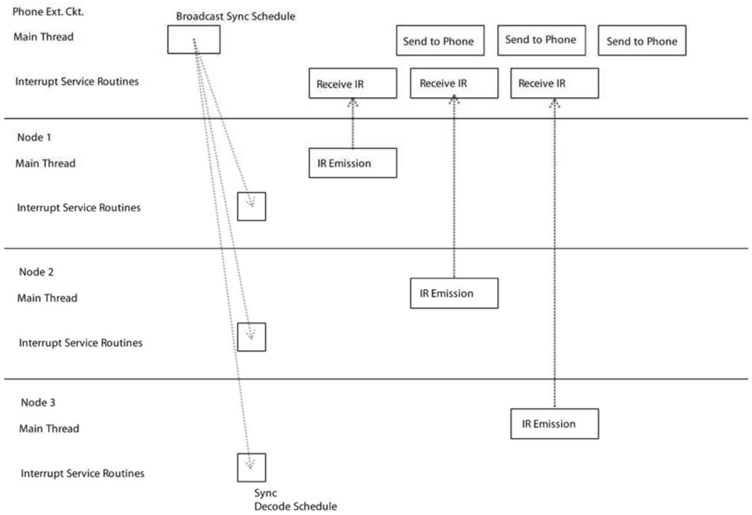
The phone radio broadcasts a schedule of IR emission, all nodes in the schedule will emit IR pulses according to the schedule, while other nodes within range who are not in the schedule will make a request to join the next schedule.

This IR emission is modulated at 38 KHz to reject ambient light, and because the receivers can be standard IR remote receivers. The protocol is designed by us, with long pulse trains compared to other protocols to ensure that the IR camera can detect the emission. The IR camera is made by PixArt exclusively for use in Wiimotes, so we had to salvage one from a Wiimote, it outputs coordinates of IR light. The IR protocol simply contains a starting pulse, the device identifier, and a checksum for data integrity.

Once the application knows the location and identity of the node, it is displayed to the user, and the user can interact with it through the touchscreen interface. Commands can be sent via the same RF transceiver, or through side-channels available on the phone.

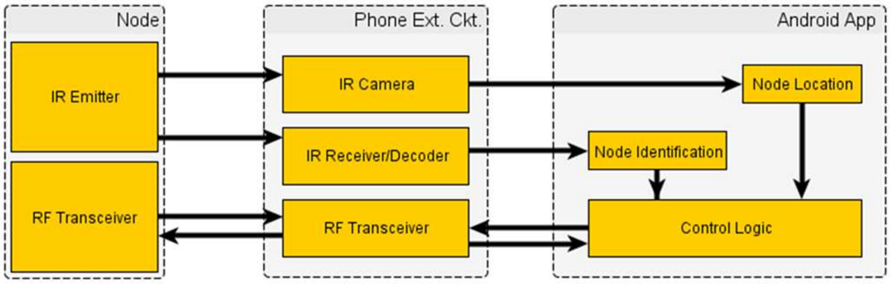
The wireless protocol is designed like UDP, simple origination and destination addresses, payload, and checksum. The packet is passed through OSI-like layers in the node firmware, with the final layer being the "application layer".

IR Scheduling



The IR scheduling uses hardware timers and interrupt service routines, so it is extremely unlikely that more than one node is emitting IR at the same time. This minimizes the chances of interference.

ARUCI Communication



This IR emission is modulated at 38 KHz to reject ambient light, and because then we can use readily available IR remote receivers. The protocol is designed by us, with long pulse trains compared to other protocols to ensure that the IR camera can detect the emission. The IR camera is made by PixArt exclusively for use in Wiimotes, so we had to salvage one from a Wiimote, it outputs coordinates of IR light. The IR protocol simply contains a starting pulse, the device identifier, and a checksum for data integrity.

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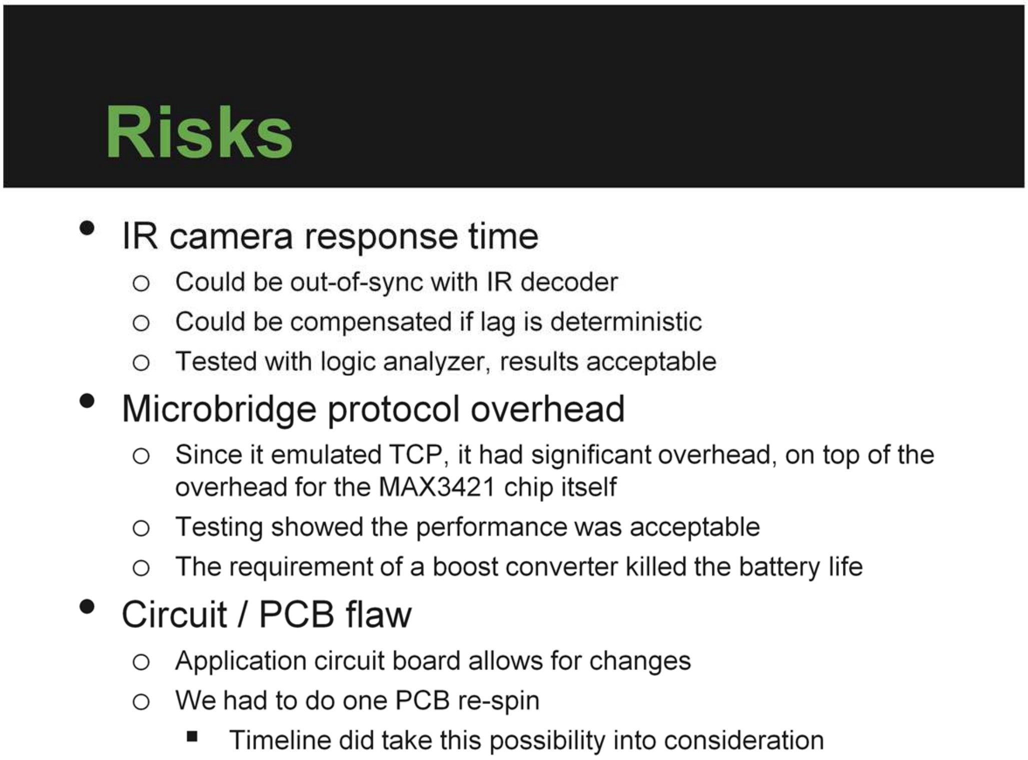


We did realize several risks in our design at the beginning.

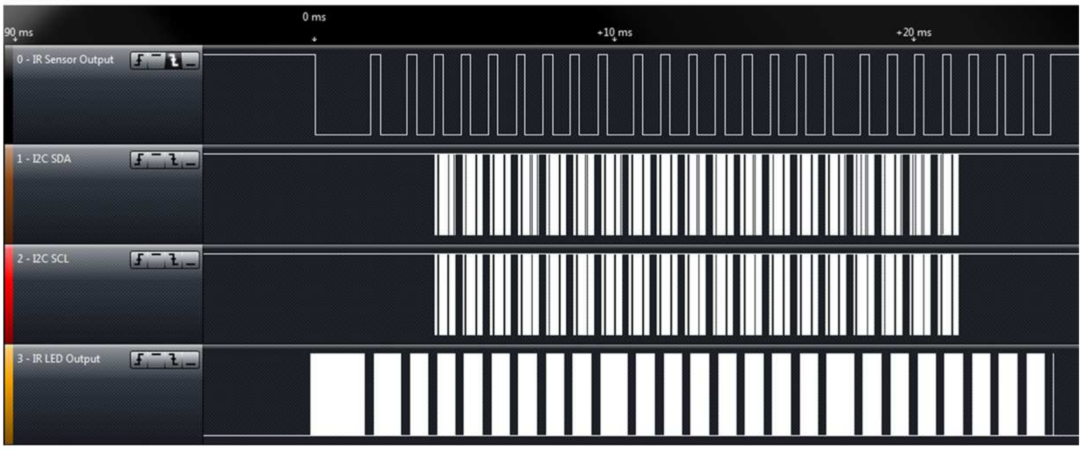
If the IR camera responded too slowly, we cannot guarantee that what it sees corresponds with the correct node that is emitting IR. But we know the lag can be compensated for if it is deterministic.

Microbridge is a protocol that used a MAX3421 chip, it emulated TCP, all the overheads combined caused performance concerns. It also ruined the battery life because a 5V boost converter was required.

We did end up making mistakes, and had to do one PCB re-spin. We planned for such an event so we did not miss any deadlines at all.

The application boards can be modified and reused.

IR Logic Analyzer Capture



This is a screenshot of us using our logic analyzer to verify that the IR camera responds in a timely fashion.

This particular capture shows that the delay between the start of IR emission and start of camera data reception is sufficiently short, and that the data rate from the camera is fast enough to fit in one packet of IR emission.

We also use the logic analyzer to verify other aspects of the system, mainly event timing and bus data.

Alternatives

- Bluetooth
  - Limited connections
- Other IEEE 802.15.4 standards (or other ISM bands)
  - ZigBee, BitCloud, etc.
    - Bloated
  - CC2000, STM32W, etc.
    - Unavailable tools and software
- Wi-Fi or XBee
  - Power hungry
  - More hardware
- Premade AR APIs (Vuforia, etc.)
  - Not flexible enough

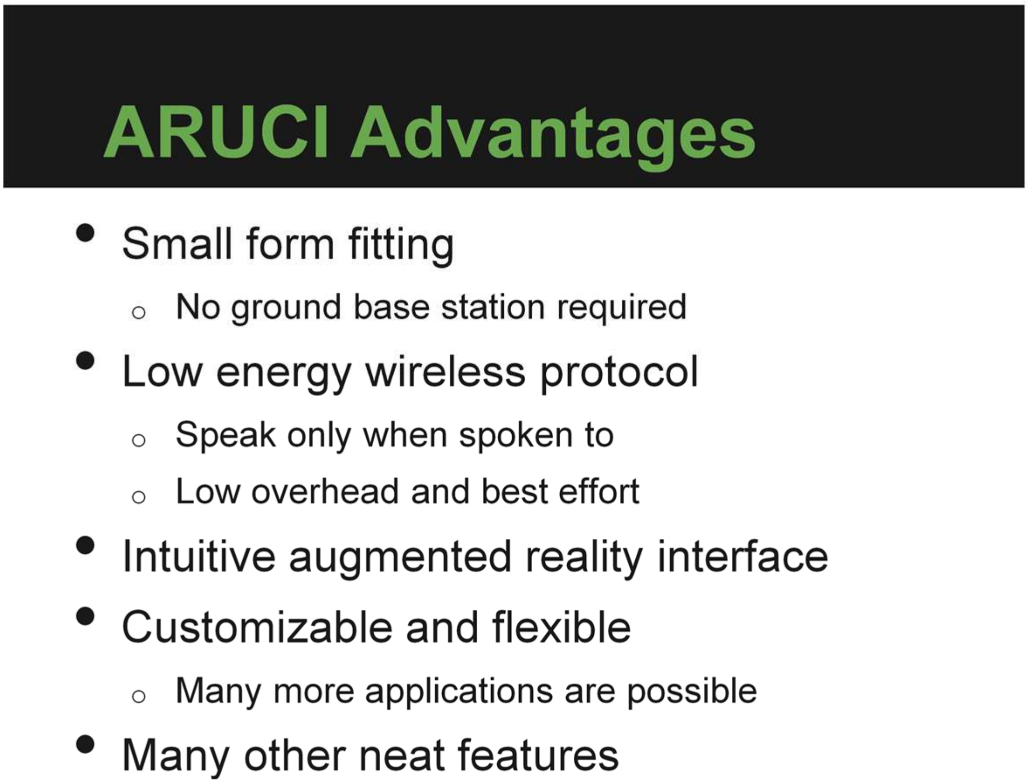
We considered other alternative technologies.

Bluetooth is an obvious choice but it only supports a limited number of connections.

There are a few alternative IEEE 802.15.4 solutions but their protocols are bloated compared to our custom protocol. Other chips are available as well but we do not own their development tools, and their software stacks are not open or free.

XBee and Wi-Fi very popular because they are easy to use, but they are power hungry and require large pieces of expensive hardware.

We did try premade augmented reality libraries for Android such as Vuforia, but found that it is heavyweight and did not make it easy for us to implement our features.



By creating the system the way that we did, the system is smaller, more efficient, and more versatile. Unlike competitors, we do not require a fixed ground base station.

Our custom wireless protocol saves energy because the nodes follow the "speak only when spoken to" rule. The removal of unnecessary overhead from our protocol allows for more bandwidth efficiency and better system performance.

Developing our own AR overlay interface is great because it only does what we need it to do, and provides us with the flexibility to make it extremely intuitive.

ARUCI is also extremely customizable, with a modular design that allows for easy addition of devices at later times. Simply swap out an application board and flash new firmware. The PCB design takes this into account by providing all the needed data busses, signals, power supply, even USB and debugging signals.

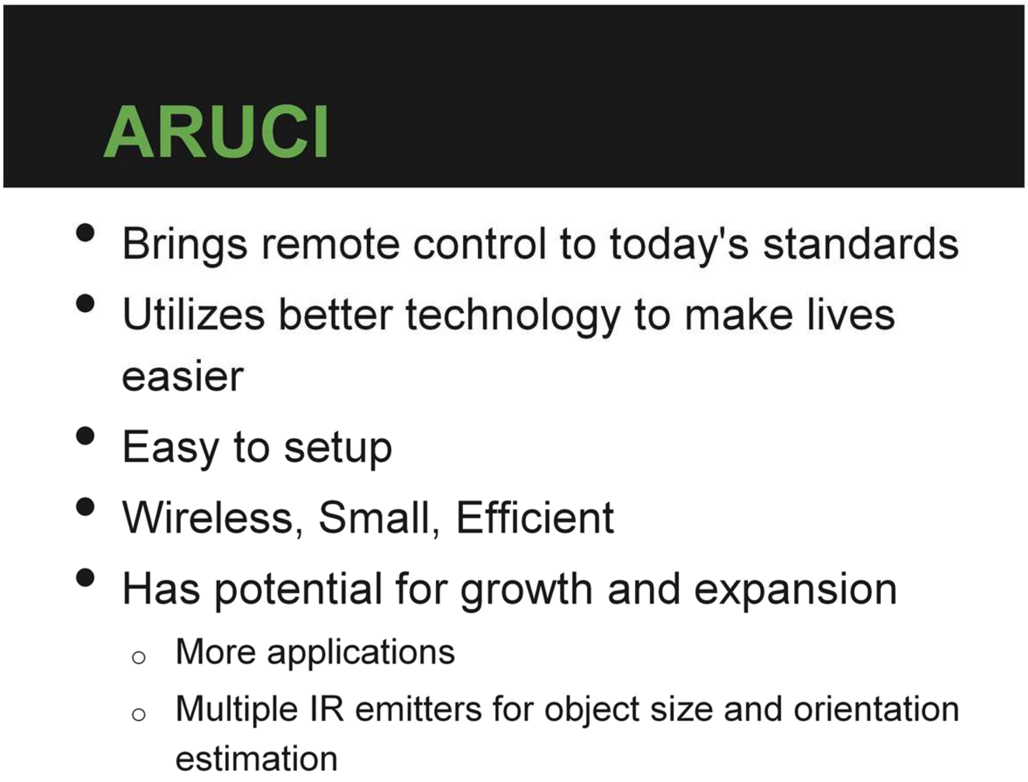
Testing ARUCI

- Prototype almost fully functional last July
- Prioritized core functionality
  - Some optional features were dropped
  - More nodes created and tested after
- Sandwich testing model was used
  - Emulation tools were developed and used

The prototype was tested in July of last year, and while there were only a 2 functioning nodes that were created for the test, the entire system worked. It identified the nodes, allowed for the control the nodes, and obtained information from the nodes.

These nodes have been expanded to 5 nodes today, and all are visible at our booth. While a few aspects of the original design had to be dropped for time and complexity's sake - such as the social networking and image recognition - the core functionality of ARUCI was operational.

The development was done from two directions, with somebody working on the nodes and somebody working from the phone. Quick tests were done using emulation tools developed by us so nobody has to wait on anybody else in order to progress.



In conlusion, ARUCI uses better technology to bring remote controls to the 21st centry and make our lives easier.

The system is easy to setup. It is wireless, small, and efficient.

We can improve the system in several ways, first, by adding even more applications. We can also add more IR emitters so the size and orientation of the object can be detected. It would also be ideal if the hardware was integrated into the phone, instead of having to attach an external circuit.

Questions?

FAQ:

- ATmega128RFA1 microcontroller for all circuits
  - 128KB flash, 4KB SRAM, 16MHz, AVR core (Harvard architecture)
  - Integrates an IEEE 802.15.4 transceiver
- Cadsoft EAGLE for PCB and schematic
  - PCB fabricated by SeeedStudio
  - Soldered by us, even the QFN footprint
- SolidWorks for 3D printed case
  - Printed by Shapeways, using SLS
- All firmware written in C
  - compiled using GNU AVR-GCC
  - Atmel Studio 6 as IDE
  - USBasp for flash programming, serial port for debugging
- Phone: Samsung Infuse 4G
  - Android OS 2.3.7, SDK version 10
- One nodes costs roughly $25, excluding the cost of the application circuit

This concludes our presentation, and we'd like to thank you all for joining us.
For more information and to see our incredible demonstrations, please come to our booth out on the main floor. We have many more neat features and advantages we can talk about.
We would now like to open the floor to questions that you might have.