UC San Diego

JACOBS SCHOOL OF ENGINEERING

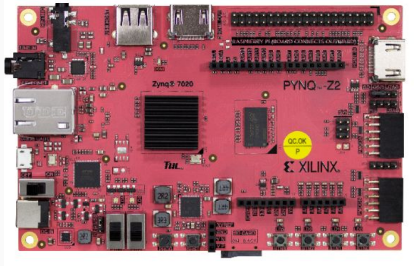
Navigation on PYNQ

"The Navericks": Patrick Hanrahan, Frank Chang, Benjamin Hobbs

WES237C Hackathon
December 7, 2018

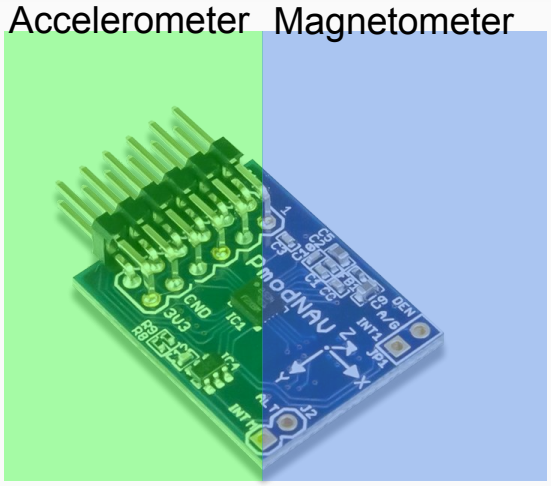
Agenda

- Overview - Ben
- System Diagram - Pat
- Sensor Interface - Frank
- HLS IP Core - Frank
- Vivado Build - Pat
- Graphical Display - Ben
- Lessons Learned



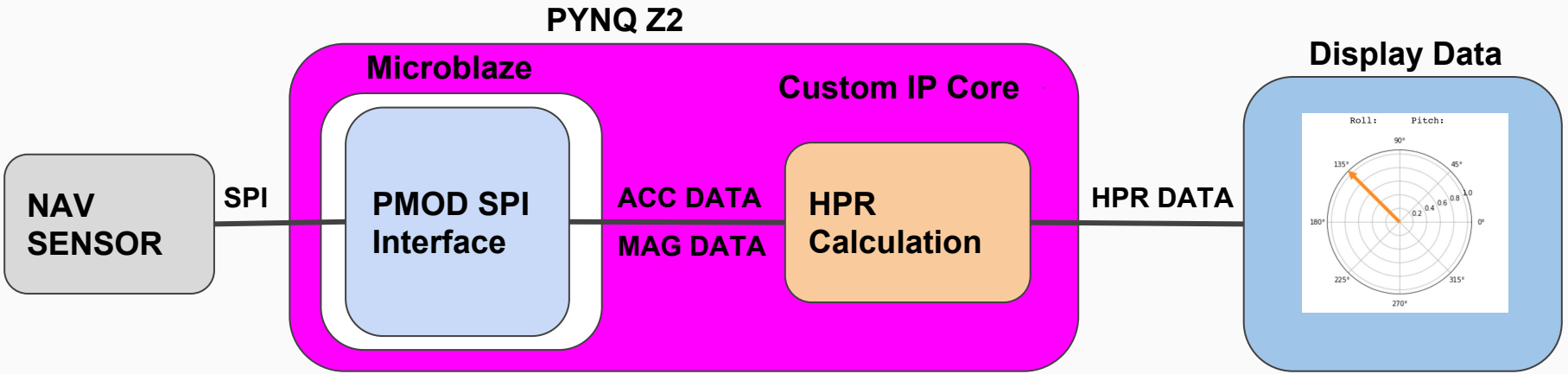
Overview

- Using Python:
  - Poll XYZ acclerometer (ACC) and magnetometer (MAG) data from the PMOD NAV unit over SPI.
  - Determine the offset error on each axis of the magnetometer device.
- Using HLS:
  - Compute heading, pitch and roll (HPR).
- Back to Python:
  - Display the tilt compensated heading info.



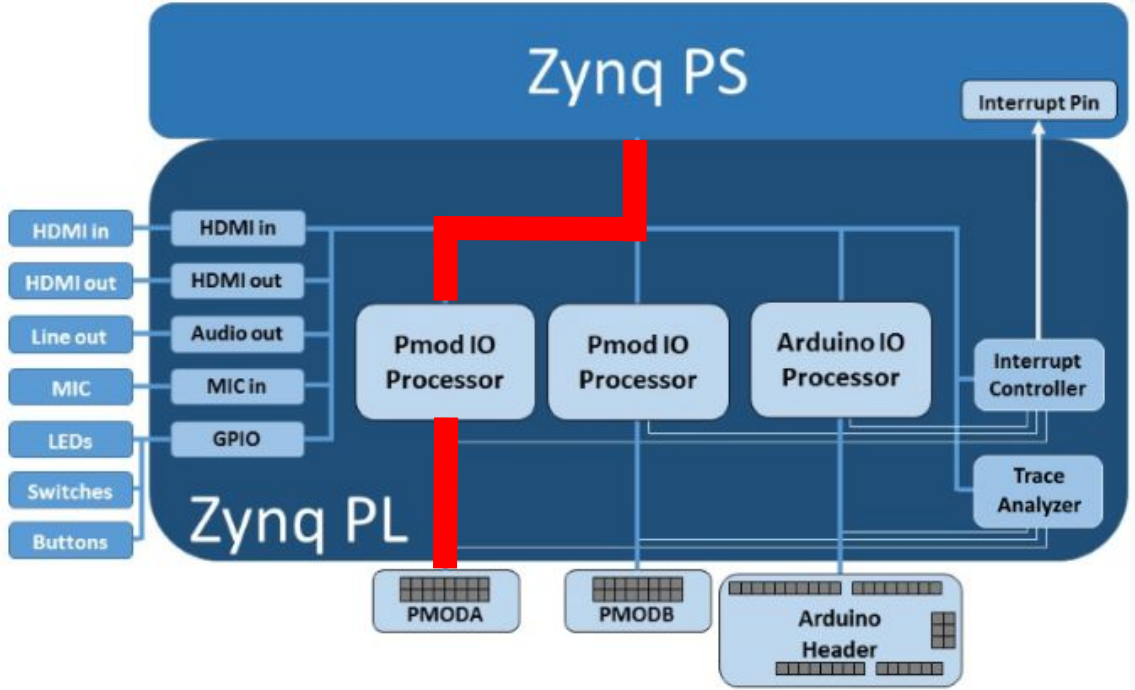
NAV

System Block Diagram



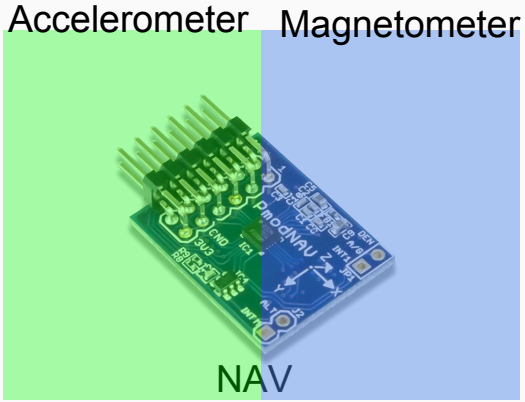
Base Overlay & Custom Overlay

- Use base overlay to interface with PMODA over SPI.
- Use custom IP core to post process sensor data in Programmable Logic



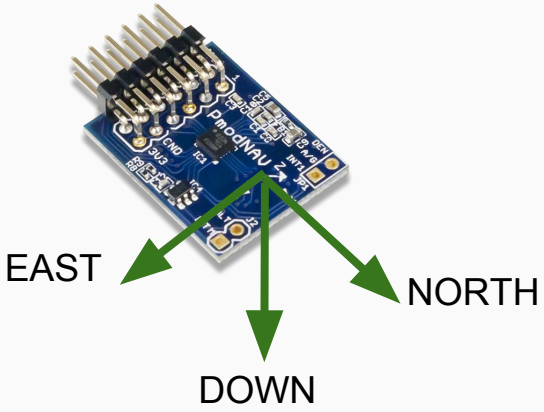
Sensor Interface: NAV PMOD

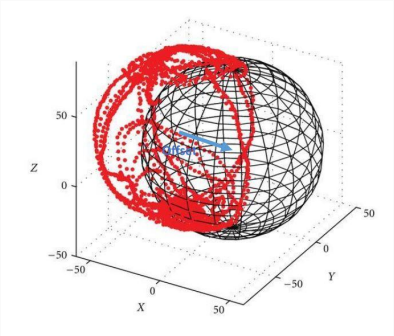
- Used MicroBlaze PMODA to interface with NAV unit over SPI.
- NAV unit uses the LSM9DS1.
- The NAV unit has several devices in one package:
  - Gyroscope - Angular (not used)
  - Accelerometer - Earth's gravity (used)
  - Magnetometer - Earth's mag field (used)
- Steps involved to get data:
  - Configure control registers.
  - Sample from ACC (16bit, +/-2g).
  - Sample from MAG (16bit, +/-4Gauss).



Sensor Interface: NAV PMOD

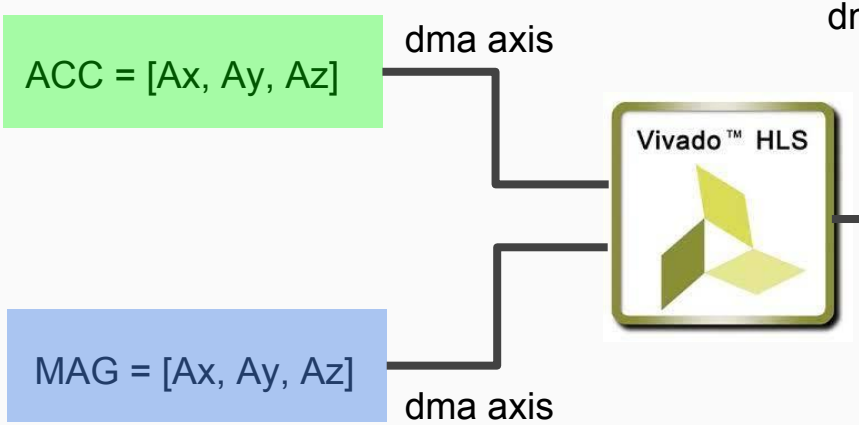
- Quick calibration:
  - Adjust offset of MAG by performing 6-axis mean calibration.
    - Flip on each side and take the mean for each axis.
    - The mean is your offset.
  - No offset calibration done on ACC.
  - Re-align ACC and MAG axis to be North-East-Down (NED) for ACC and MAG.





MAG data with offset.

Sensor Data Processing: HLS IP Core



Performance Estimates

Timing (ns)

Summary

Clock	Target	Estimated	Uncertainty
ap_clk	10.00	8.750	1.25

Latency (clock cycles)

Summary

Latency		Interval		
min	max	min	max	Type
147	1012	147	1012	none

Detail

Instance

Loop

Utilization Estimates

Summary

Name	BRAM_18K	DSP48E	FF	LUT
DSP	-	-	-	-
Expression	-	-	0	153
FIFO	-	-	-	-
Instance	20	217	18457	29045
Memory	-	-	-	-
Multiplexer	-	-	-	770
Register	-	-	1460	-
Total	20	217	19917	29968
Available	280	220	106400	53200
Utilization (%)	7	98	18	56

Compute:

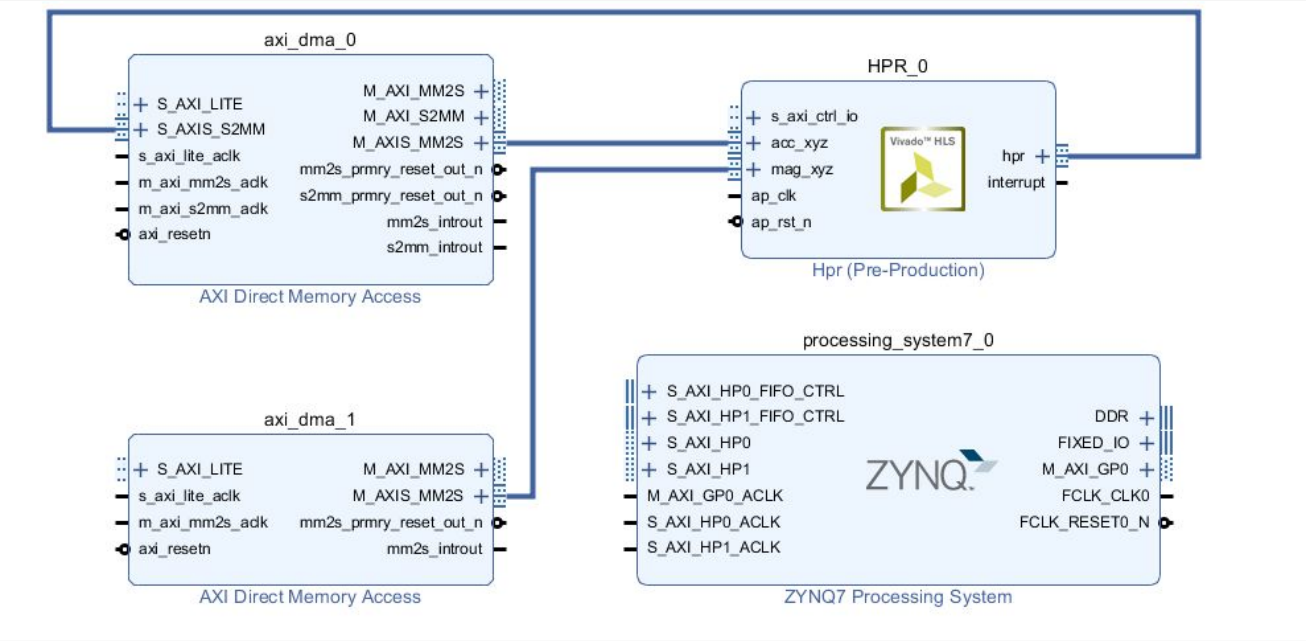
1. roll = atan2(Ay, Az)
2. pitch = atan2(Ax, Ay*sin(roll)+Az*cos(roll))
3. Rotate [Mx, My, Mz] based on roll and pitch.
4. heading = atan2(My, Mx)

Throughput = 113MHz

*heading with respect to magnetic north.

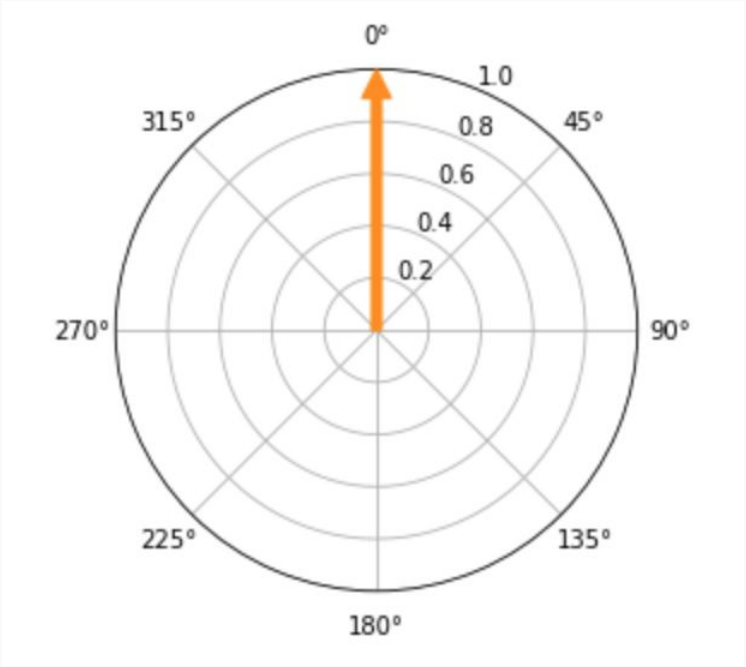
Nav Data Processing:
Vivado Build & Bitstream Generation

- Two DMA input interfaces: MAG and ACC X,Y,Z axis data
- One DMA output interface: Heading, Pitch, and Roll data



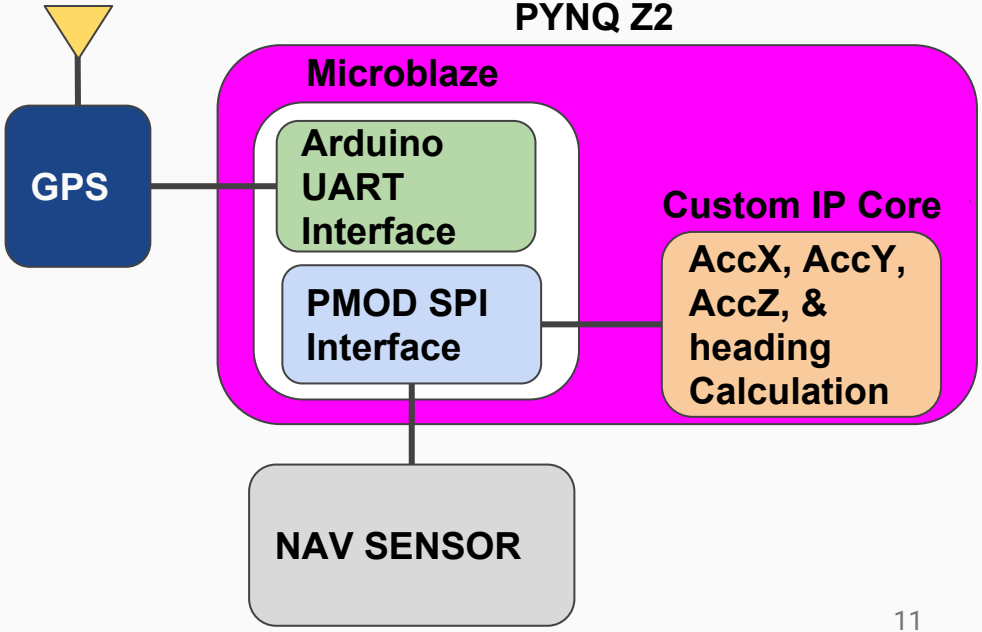
Display Data

- Calculate cos() and sin() of data.
- Plot using Polar coordinates, initialized with 0 degrees at ‘N’
- Used Dynamic plotting to constantly clear and update.



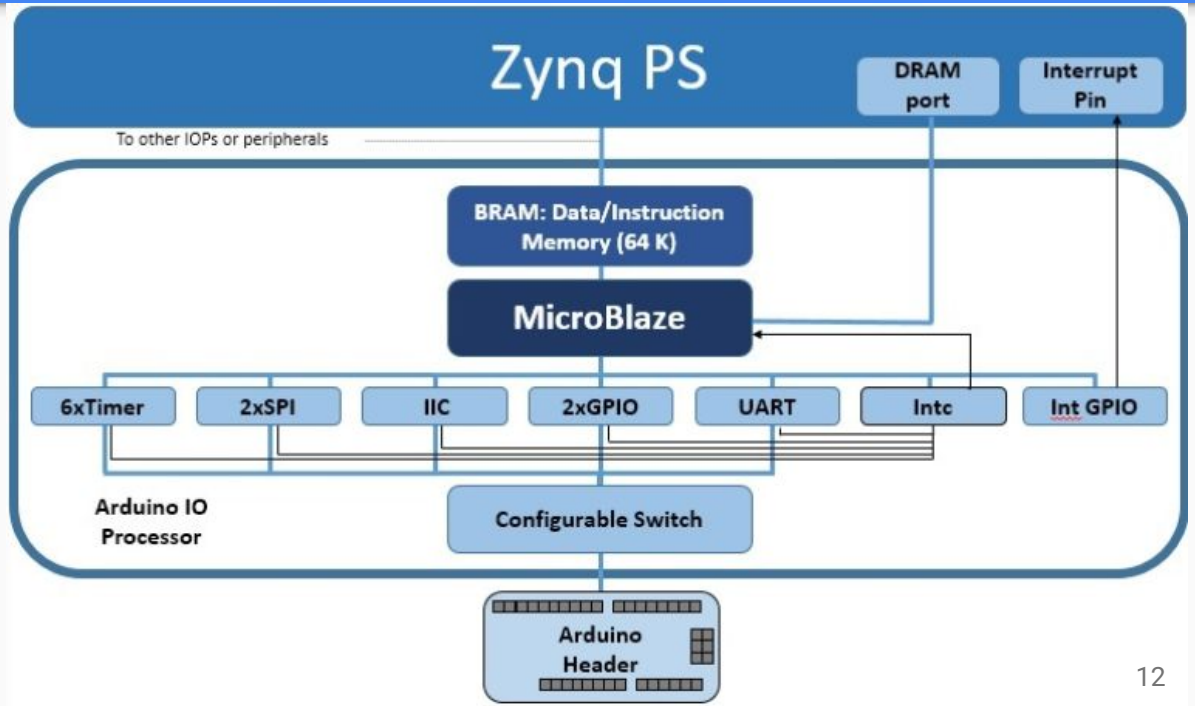
Lessons Learned

- Communicating between GPS and PYNQ more time consuming than imagined.
- HLS could be further optimized using cordic and fixed point arithmetic.
- Creating custom overlay with SPI, UART difficult to implement.
- Plotting on Python Dynamically



Lessons Learned: PYNQ UART

- UART not supported on PMOD
- Microblaze ARDUINO IO Processor may be configured for UART using io switch (only 9600 BAUD)



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Vivado™ HLS

PYNQ Z2

Microblaze

Custom IP Core

NAV SENSOR

SPI

PMOD SPI Interface

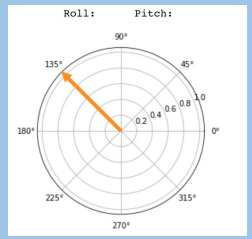
ACC DATA

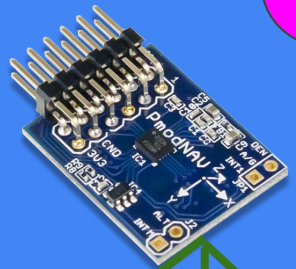
MAG DATA

HPR Calculation

HPR DATA

Display Data

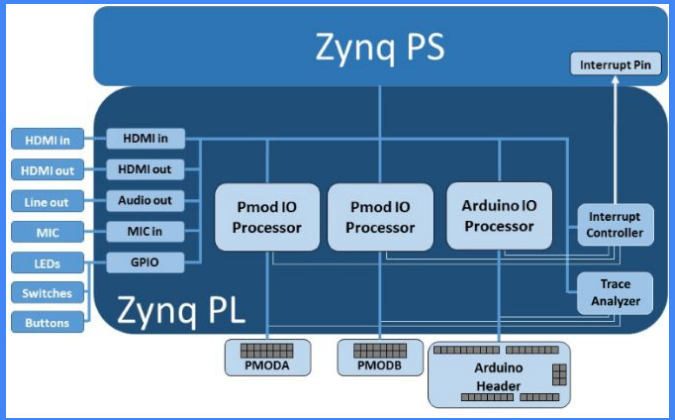




EAST

NORTH

DOWN



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