GAIT MONITORING SYSTEM
- SAFEWALK -

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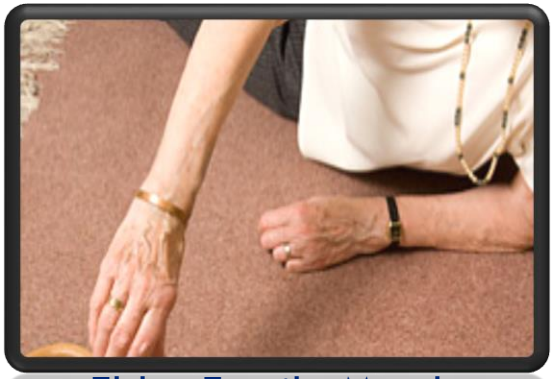
Wireless Sensor Network 18-748 March 8th, 2017

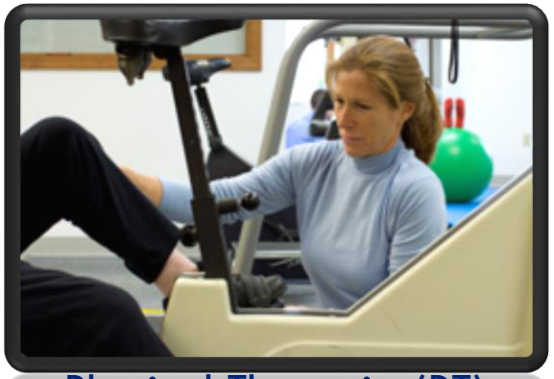
Agenda

- Problem / Solution / Use Case
- System Configuration
- Goals and Technical components
- Demo Plans
- Role & Responsibility
- Schedule

Problem



Elder Family Member

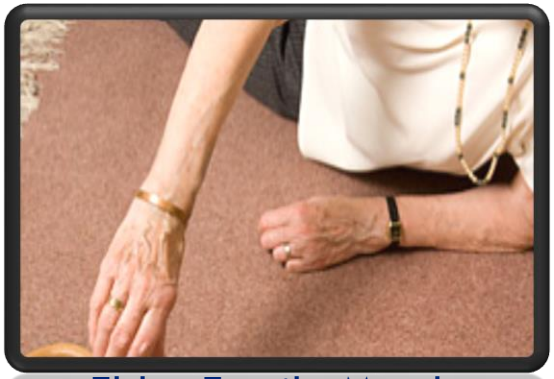


Physical Therapist (PT)

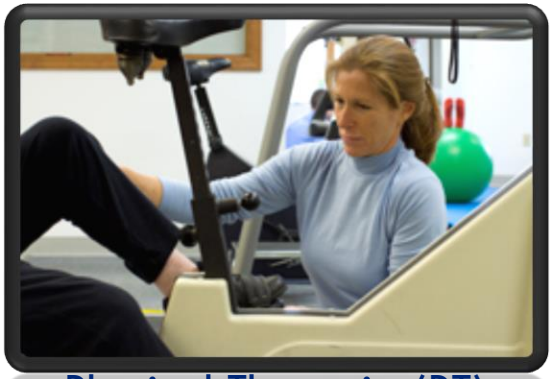
Family

- Falls frequently
- Lives with constant fear
- Faces long-term medicalization

Problem



Elder Family Member

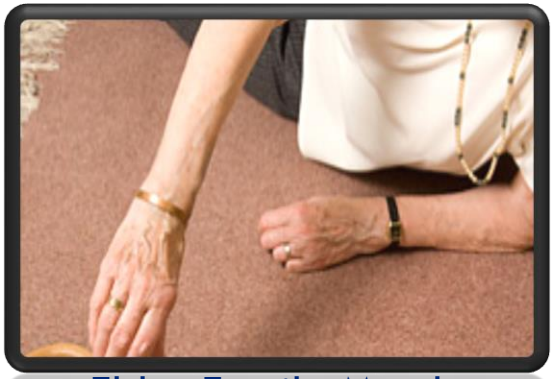


Physical Therapist (PT)

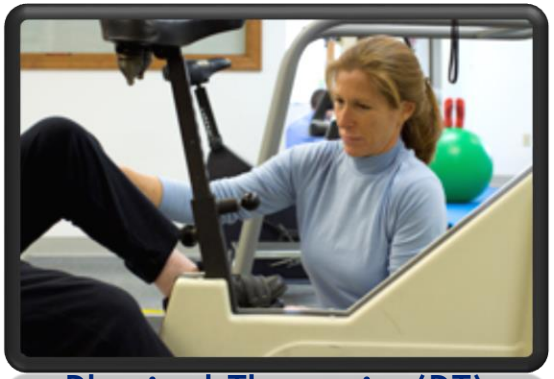
Family

- It would be very beneficial for me to know what **activities my patients engage in outside of their therapy sessions**. It is not enough for a patient to follow recommended exercises during their sessions if they do not practice them…

Problem



Elder Family Member



Physical Therapist (PT)

Family

- Little time with elder family member
- Fearful of family member falling

Solution

SafeWalk

- Measures Gait using wireless sensor network
- Helps Doctor/Physical Therapist monitor patients

Gait Measurement Parameters

Knee extension

Stride length

Gait Speed, Cadence, Double Stance Time, Swing Time, Swing Time Variability, Cadence Variability, Chair Time Rise, Ability to do Tandem Stance, Lower extremity muscle strength

Use Case

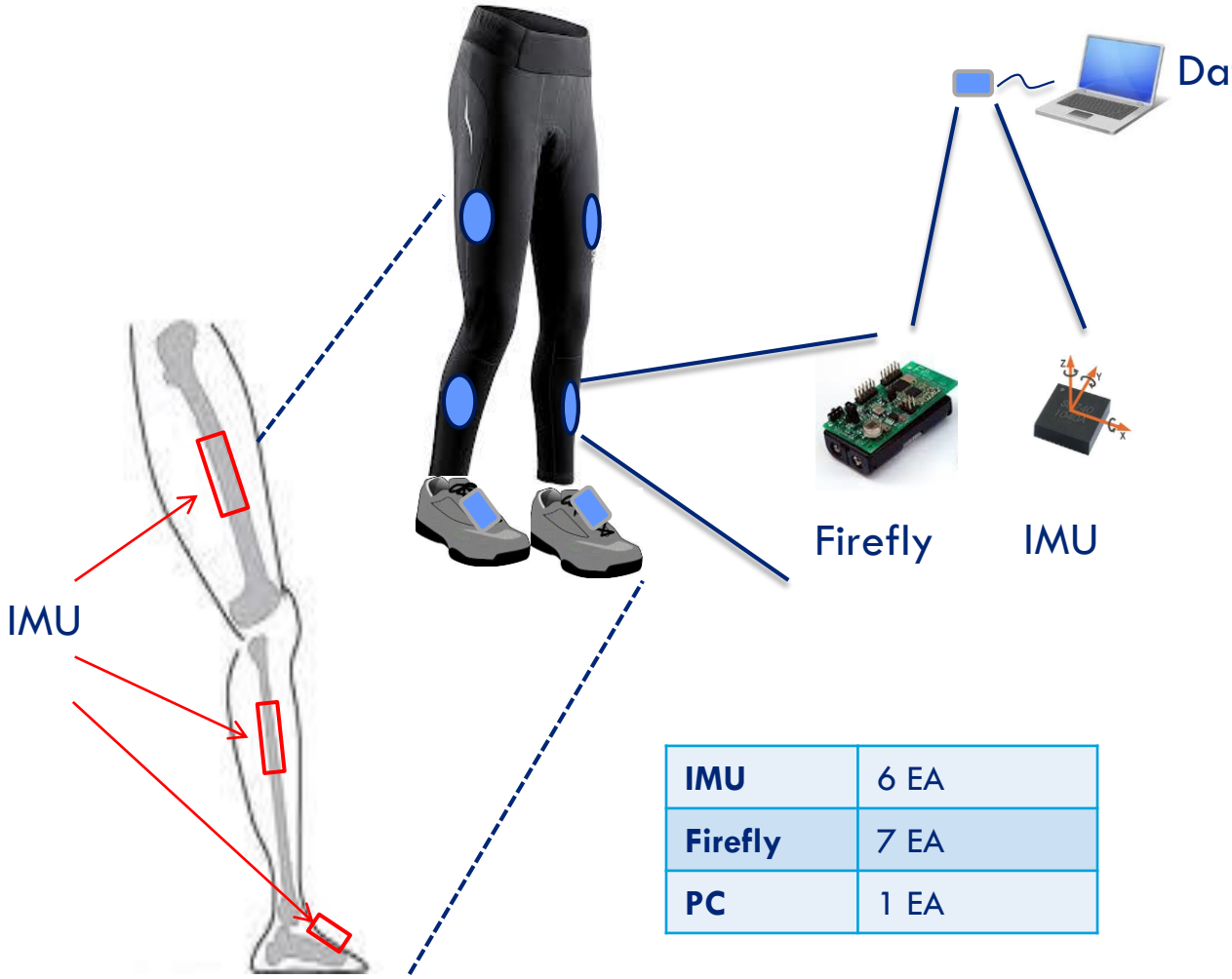
Hospitals

Nursing Homes

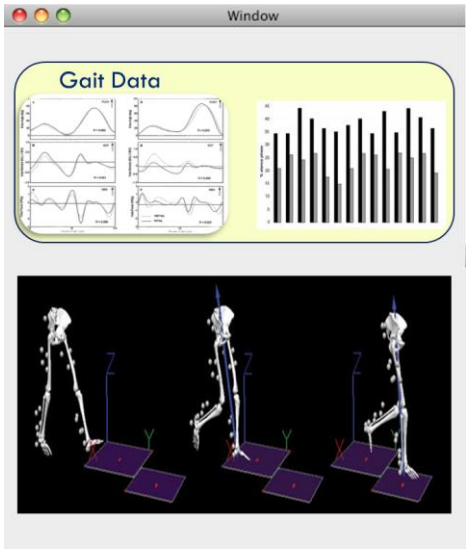
SafeWalk

Patients

System Configuration



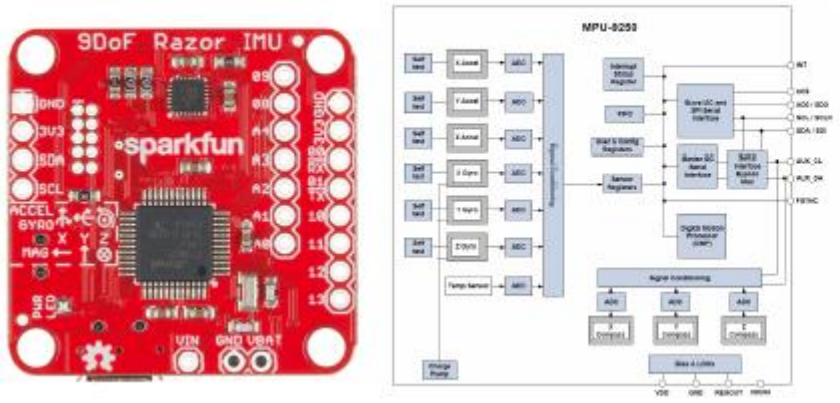
Firefly IMU



IMU	6 EA
Firefly	7 EA
PC	1 EA

9-Axis IMUs Devices

SparkFun 9DoF Razor IMU M0



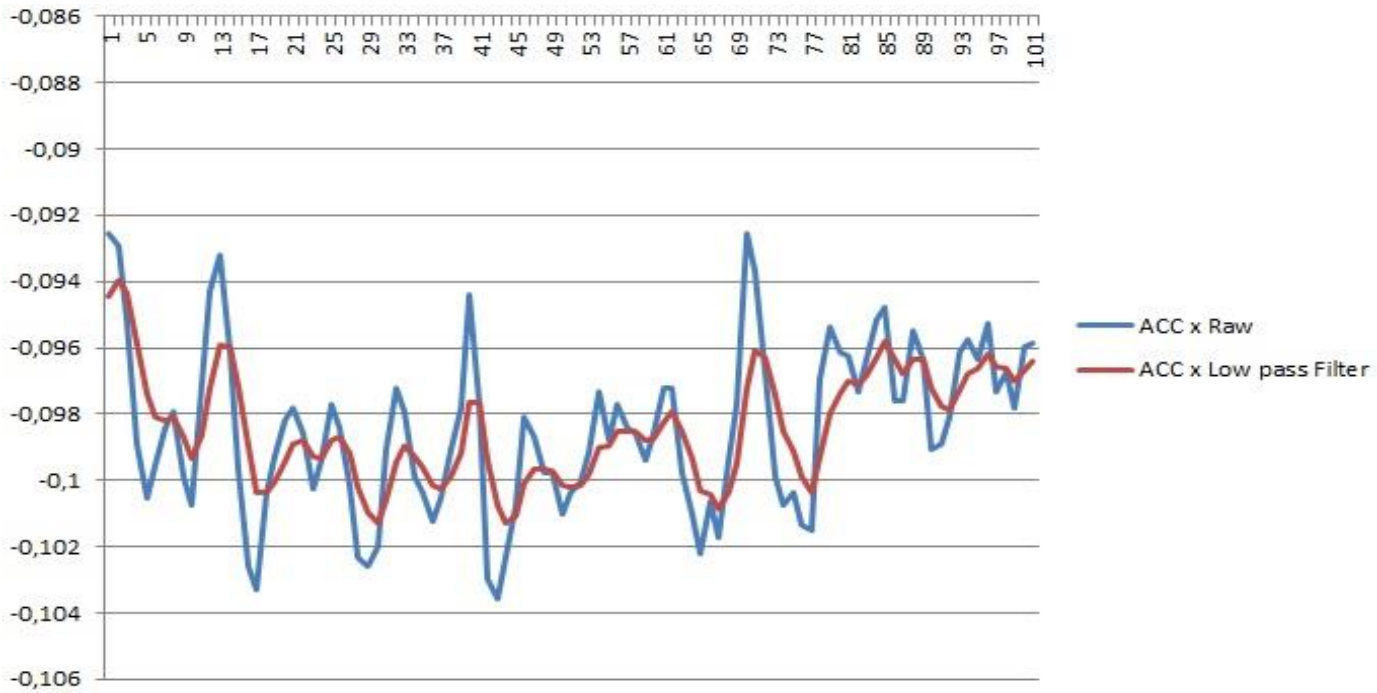
- Price: $50
- Quantity: x6~4
- Update rate: 100Hz
- Built-in low-pass filter
- Relatively low accuracy
- Mount point: thigh + calf + (foot)

3-Space Embedded IMU

- Price: $150
- Quantity: x0~2
- Update rate: 250Hz
- Built-in Kalman filter
- Relatively high accuracy
- Mount point: (foot)

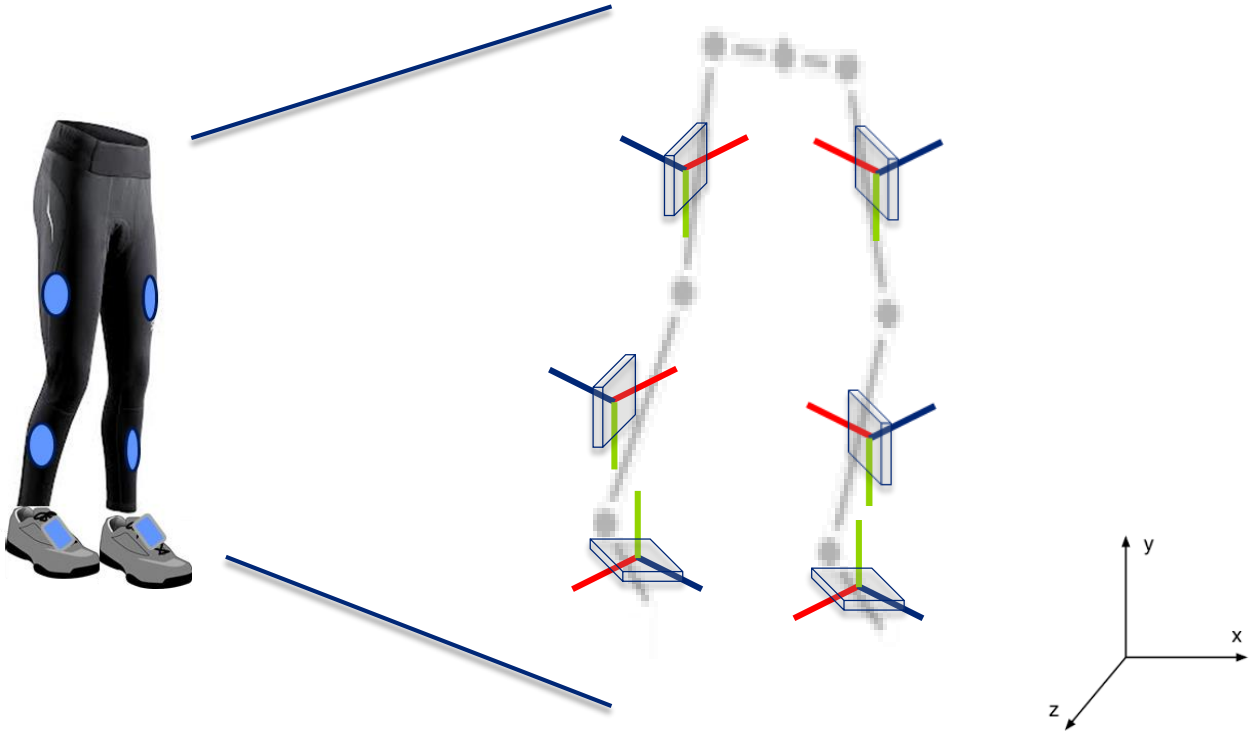
IMU Data Process

- Noise cancellation & Estimation
  - Low Pass filter (a smoother)
  - Kalman Filter (a tracker to fuse acc+gyro with mag)



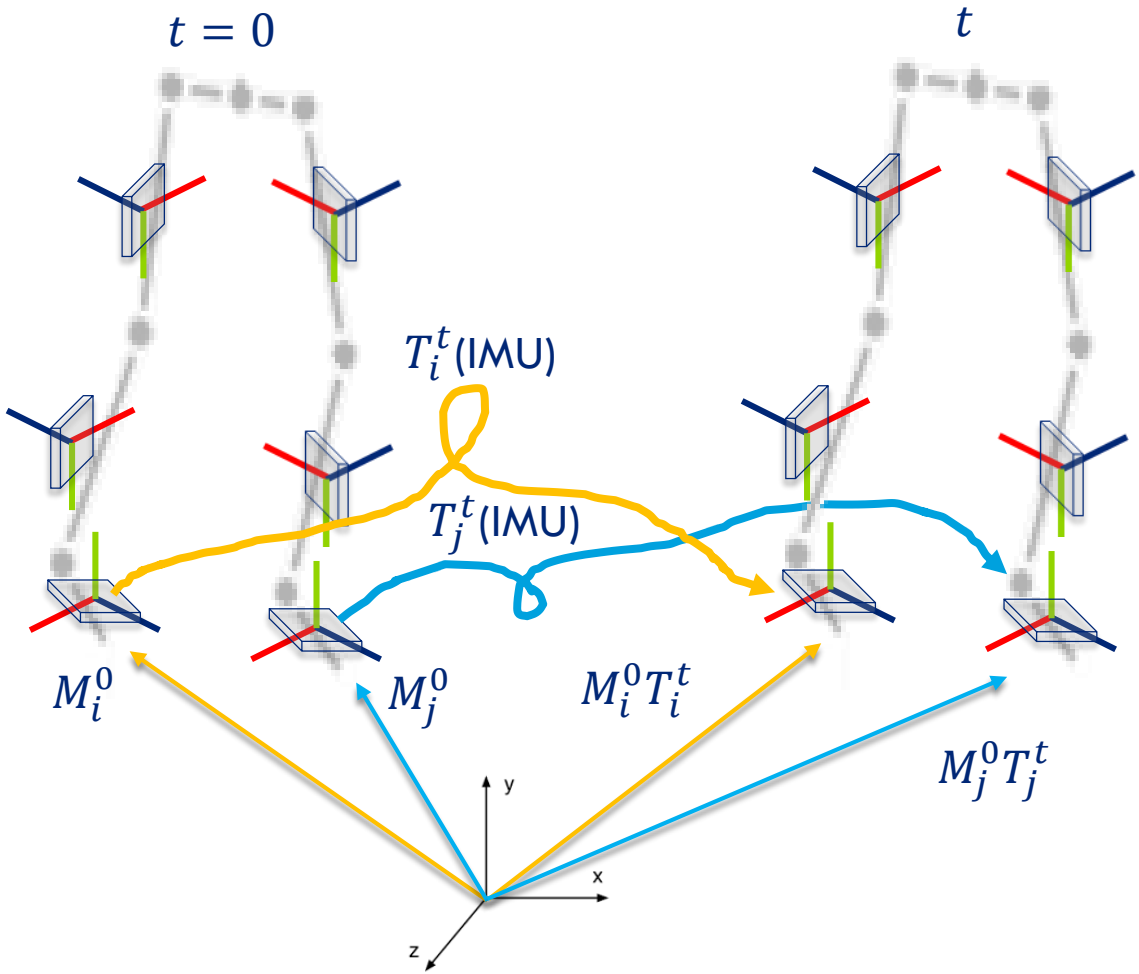
Multiple IMUs Calibration

- Get IMUs' Position & Orientation in a Unified Coordinate
  - Visualization
  - Gait data association



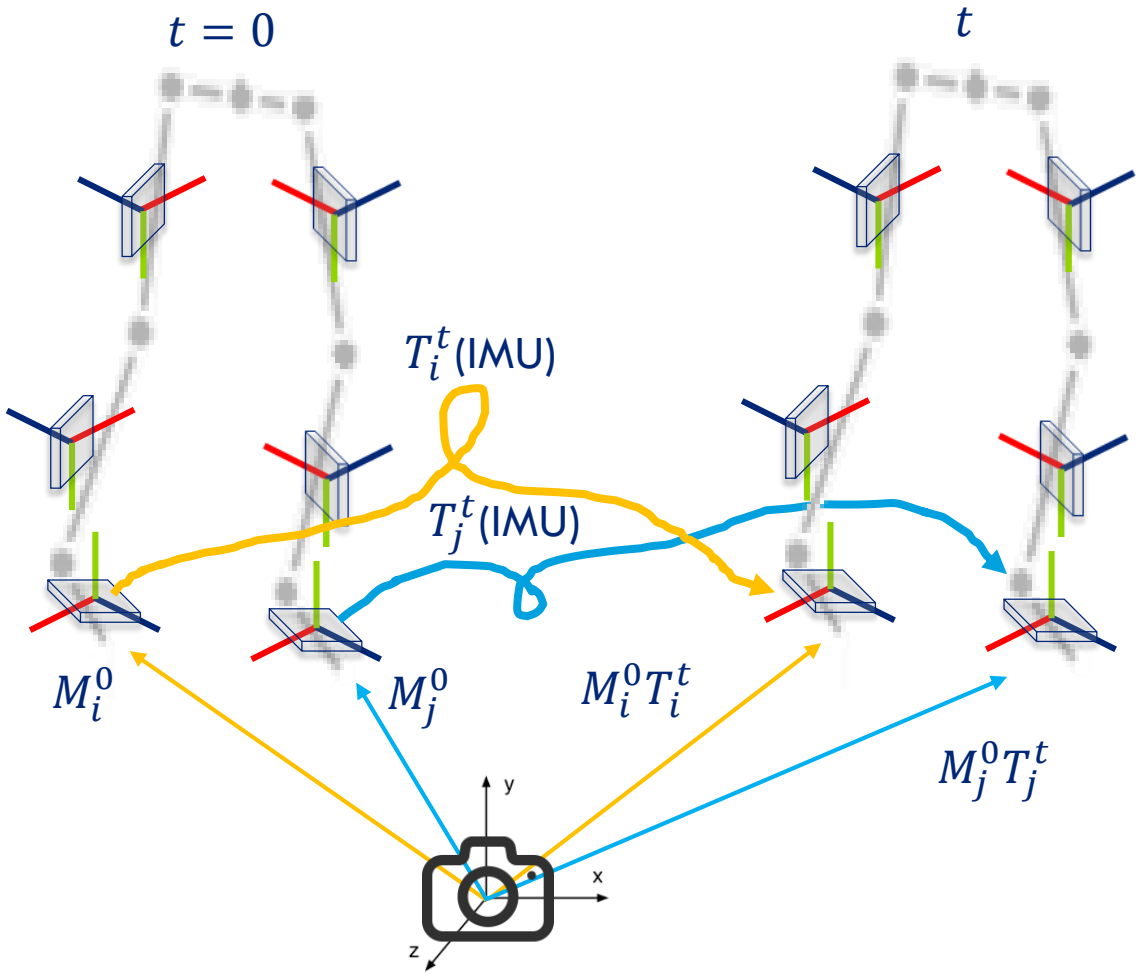
Calibration Method

- Calibration Target: Initial (T=0) Position & Orientation



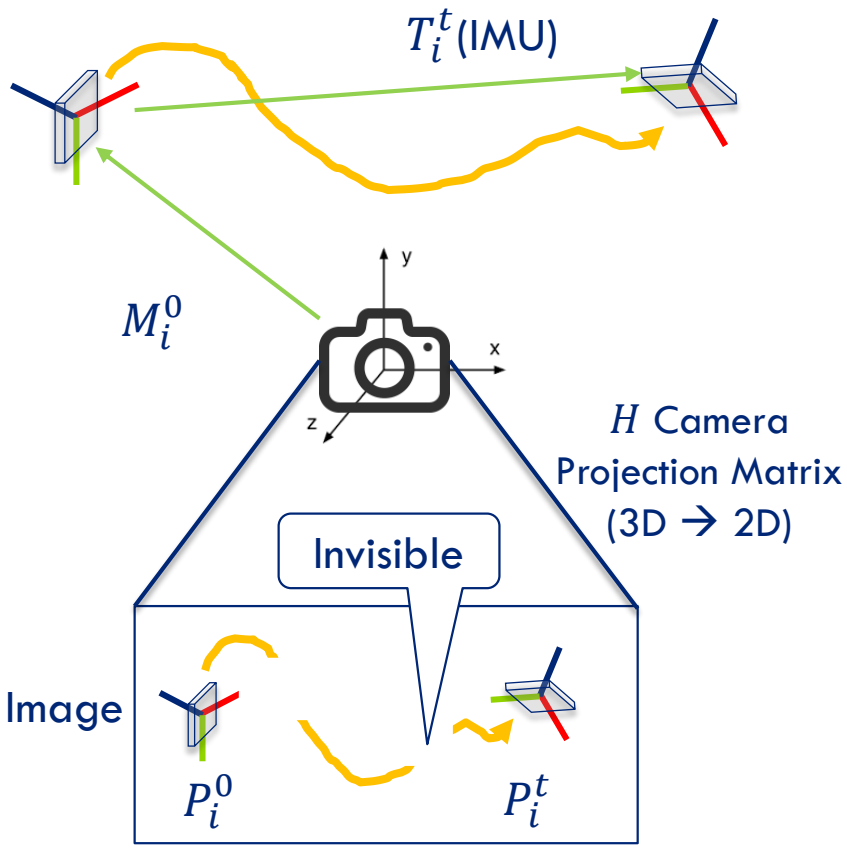
Calibration Method

- Unified Coordinate for Calibration: Fixed Camera



Calibration Method

- Camera Based Calibration



Solution:

$$\begin{cases} HM_i^0 T_i^{t=t_1} = P_i^{t=t_1} \\ HM_i^0 T_i^{t=t_2} = P_i^{t=t_2} \\ \dots \\ HM_i^0 T_i^{t=t_n} = P_i^{t=t_n} \end{cases}$$

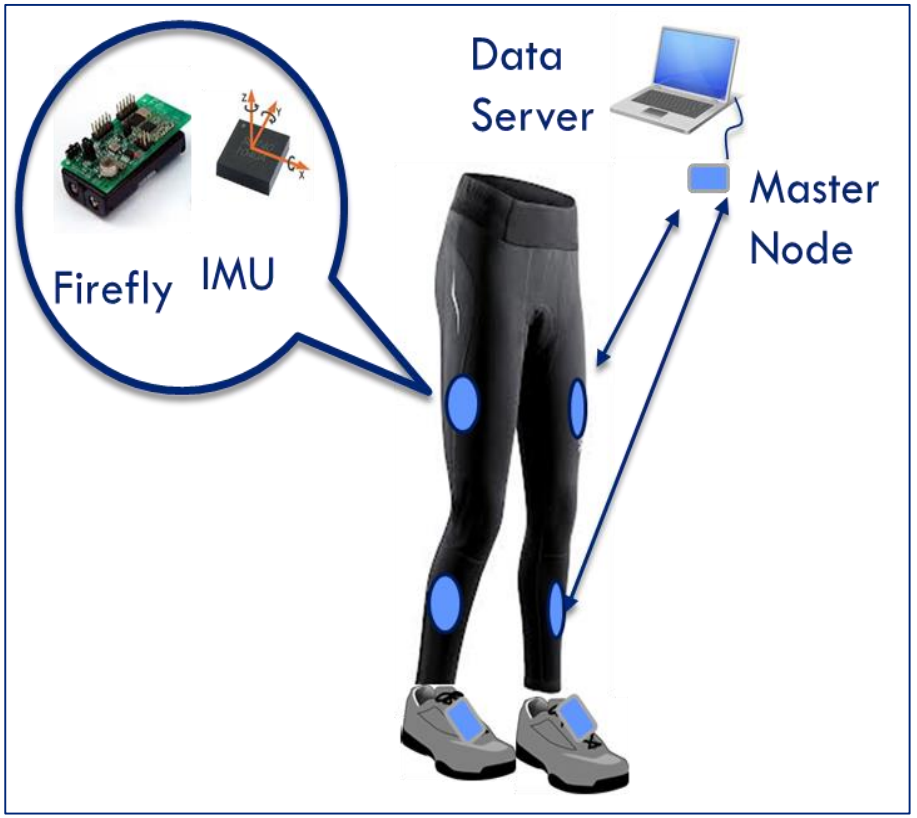
where $\{t_1, t_2, \dots, t_n\}$ is the visible time set

Keys:

- Require tight time synchronization
- Need as many paired data as possible
- Need to handle IMU accumulated error
  - Time-weighted LSE
- Manually locate IMU on images
  - CV track method is possible
  - RANSAC to get rid of wrong data

Data Communication

- Master-to-slave
- Packet loss detection
- Synchronization
- Data logging

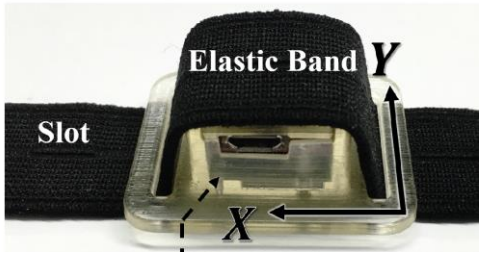


Gait Data Analysis

- Gait Speed
- Cadence
- Stride Length
- Double Stance Time
- Knee extension
- Swing Time
- Stride Length Variability
- Swing Time Variability
- Cadence Variability

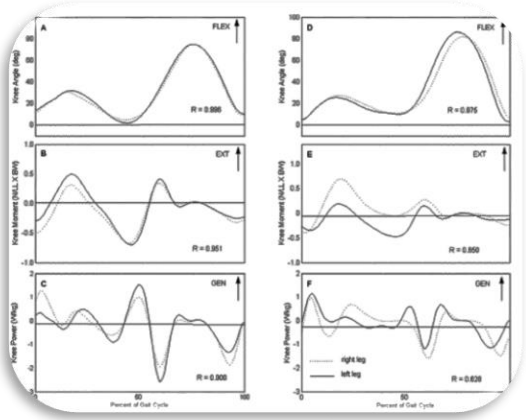
Fabrication

- Sensor Enclosure box Design & Fabrication

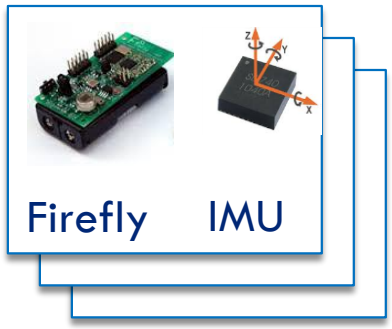


Visualization

- Visualization
  - Data
  - Motion (Extra work)



Operating system



…

Data server

ROS

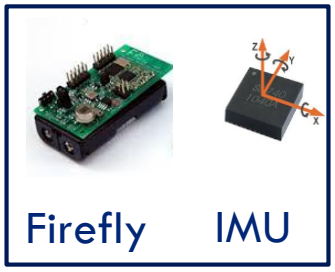
- Data Communication (Topology, Error recovery..)
- Multiple IMU Calibration (Manual, Automatic)
- IMU Data Process (Noise, Estimation etc.)

- Data Communication (Topology, Error recovery..)
- Multiple IMU Calibration (Manual, Automatic)
- IMU Data Process (Noise, Estimation etc.)
- Gait Data Analysis
- Visualization
- Data Logging

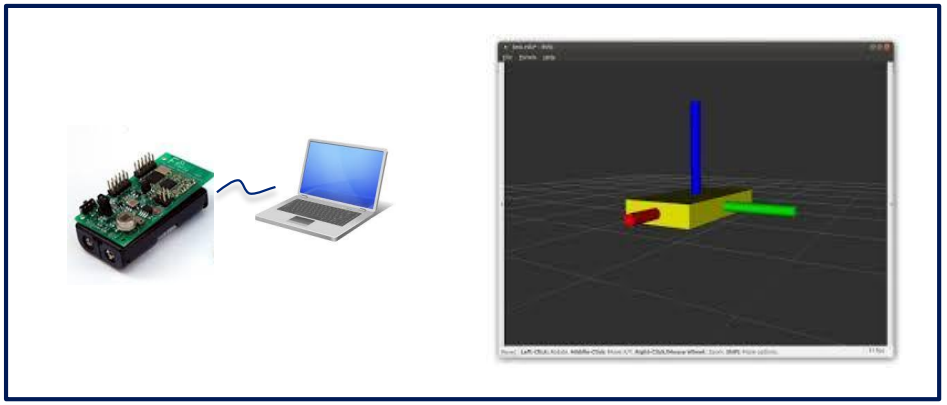
Intermediate Demo

- Implement entire pipe line with single IMU

Sensor node



Data Server

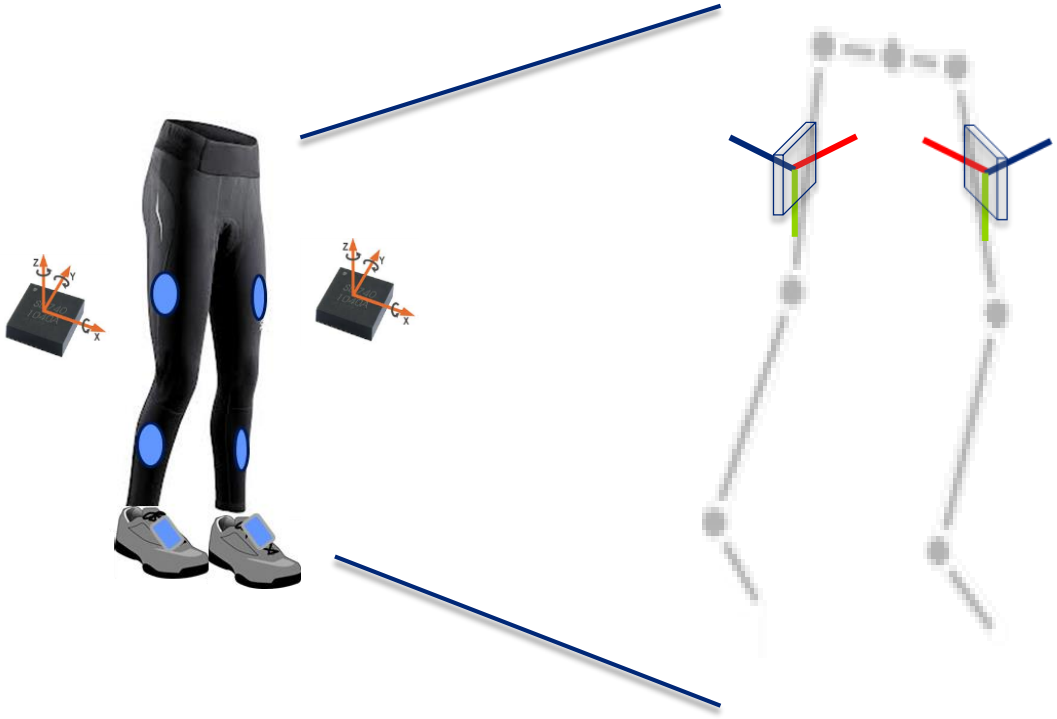


- Data Communication
- Single IMU Calibration
- Single IMU Data Process

- Data Communication
- Single IMU Calibration
- Single IMU Data Process
- Visualization (Single IMU)

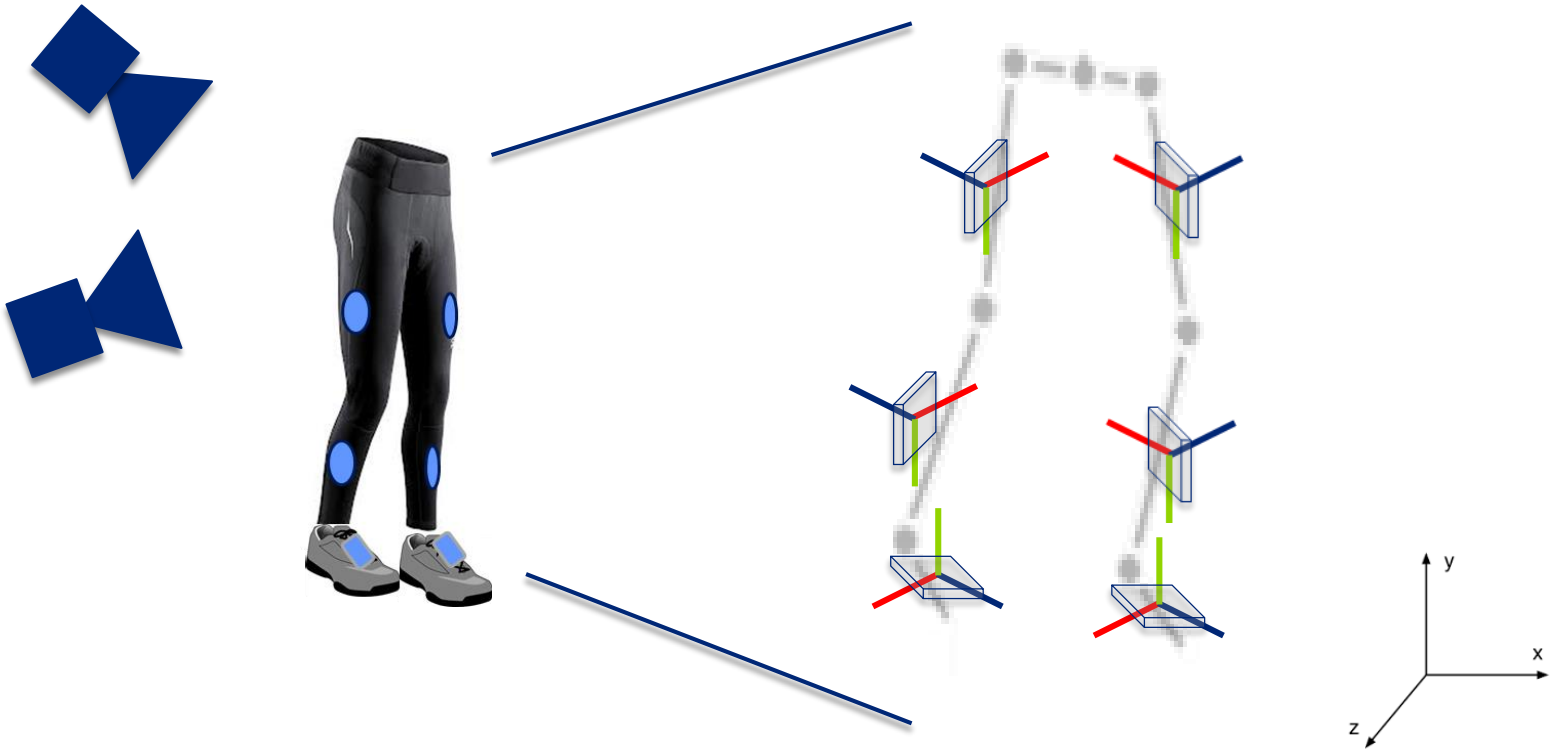
Intermediate Demo

- Calibration with two IMUs



Final Demo

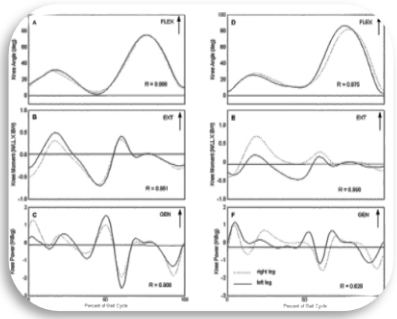
- Multiple IMU Calibration

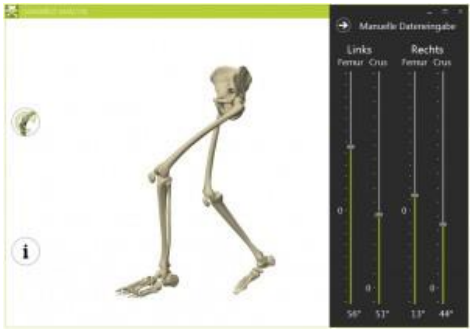


Final Demo

- Live Real-time Demo
- Real-time warning
  - Gait-Change Detection

Shunsuke



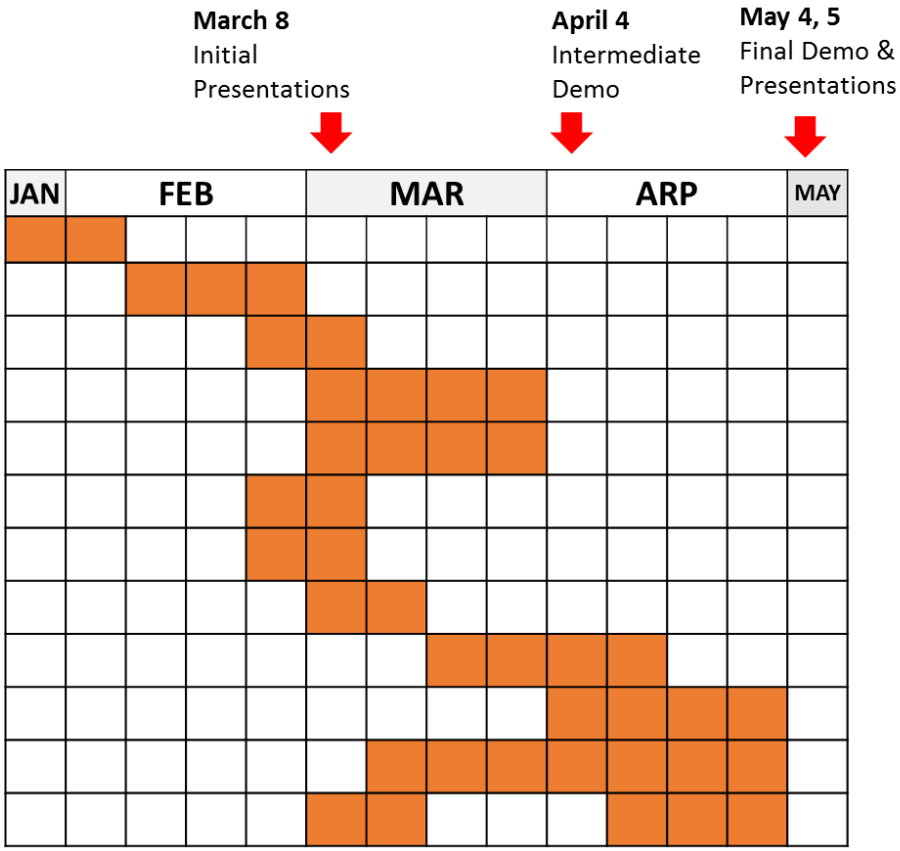


Role & Responsibility

- EMILY
  - Communication between nodes
  - IMU to Firefly data transfer
  - Gait pattern analysis
- ALEX
  - Multiple IMU Calibration
  - IMU Data Processing
  - Data transfer from master node to PC
- ILJOO
  - Gait pattern analysis
  - Data visualization & logging
  - Enclosure fabrication

Schedule

Dev. Environment setup	Project Proposal
	Study existing technology and literature
	Platform setup
Communication	Comm. Between node and data PC (Iljoo)
	Comm. Between IMU and Node (Emily)
	Define protocol (Iljoo)
Calibration	Search IMU Product (Alex, Emily)
	Individual IMU calibration (Emily, Alex)
	Multiple IMU calibration (Emily, Alex)
Analysis	Algorithm to extract Gait information
	Visualize gait information (Iljoo)
Fabrication	Attach node to body



Project Website

- https://17s-wsn-proj.github.io/Website/index.html

Safe Walk – Gait Monitoring System (17S WSN Project)

Emily Ruppel, Iljoo Baek, Mengwen He (Team 11)

Contents

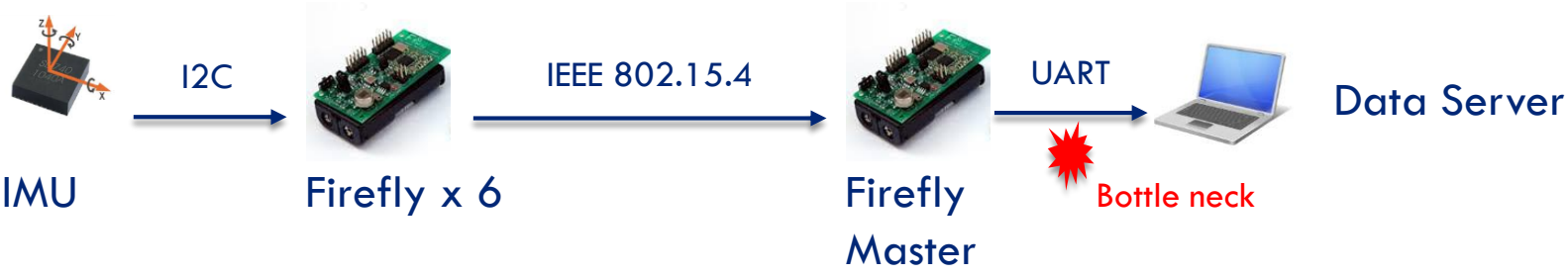
Reference

- Anatomical Calibration through Post-Processing of Standard Motion Tests Data
  - http://www.mdpi.com/1424-8220/16/12/2011/htm
- Gait Analysis Using Wearable Sensors
  - http://www.mdpi.com/1424-8220/12/2/2255/htm
- Symbolic Modelling of Dynamic Human Motions
  - http://www.intechopen.com/books/biosensors/symbolic-modelling-of-dynamic-human-motions#
- Assessment of walker-assisted gait based on Principal Component Analysis and wireless inertial sensors
  - http://www.scielo.br/pdf/rbeb/v30n3/03.pdf
- Gait and Foot Clearance Parameters Obtained Using Shoe-Worn Inertial Sensors in a Large-Population Sample of Older Adults
  - file:///C:/Users/iljoo/Downloads/sensors-14-00443.pdf
- Automatic pairing of inertial sensors to lower limb segments – a plug-and-play approach
  - https://www.degruyter.com/downloadpdf/j/cdbme.2016.2.issue-1/cdbme-2016-0155/cdbme-2016-0155.pdf

Q&A

Questions?

Appendix : Bandwidth



	Data Name	Data type	Size (byte)
ID	ID	unsigned long	4
Sequence	Seq	unsigned long	4
	TimeStamp	unsigned long	4
	accelX	float	4
	accelY	float	4
	accelZ	float	4
	gyroX	float	4
	gyroY	float	4
	gyroZ	float	4
	magX	float	4
	magY	float	4
Raw Data	magZ	float	4
	qw	float	4
	qx	float	4
	qy	float	4
quaternion	qz	float	4
	pitch	float	4
	roll	float	4
Euler angle	yaw	float	4
Total			76

- IEEE 802.15.4 : 250 Kbps = 32,000 bytes/sec
- UART : 115,200 baud = 11,520 bytes/sec
- One sample : 40 x 2 = 80 bytes
- # of nodes : 6

IMU Freq (Hz)	Data (Bytes)
100	48,000
50	24,000
30	14,400
20	9,600

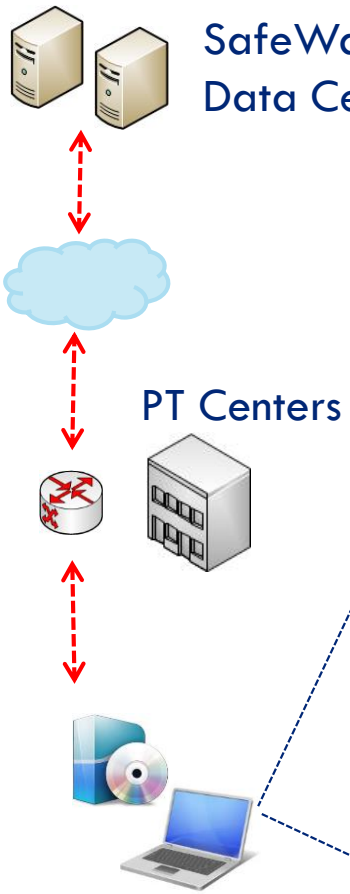
Appendix : Battery

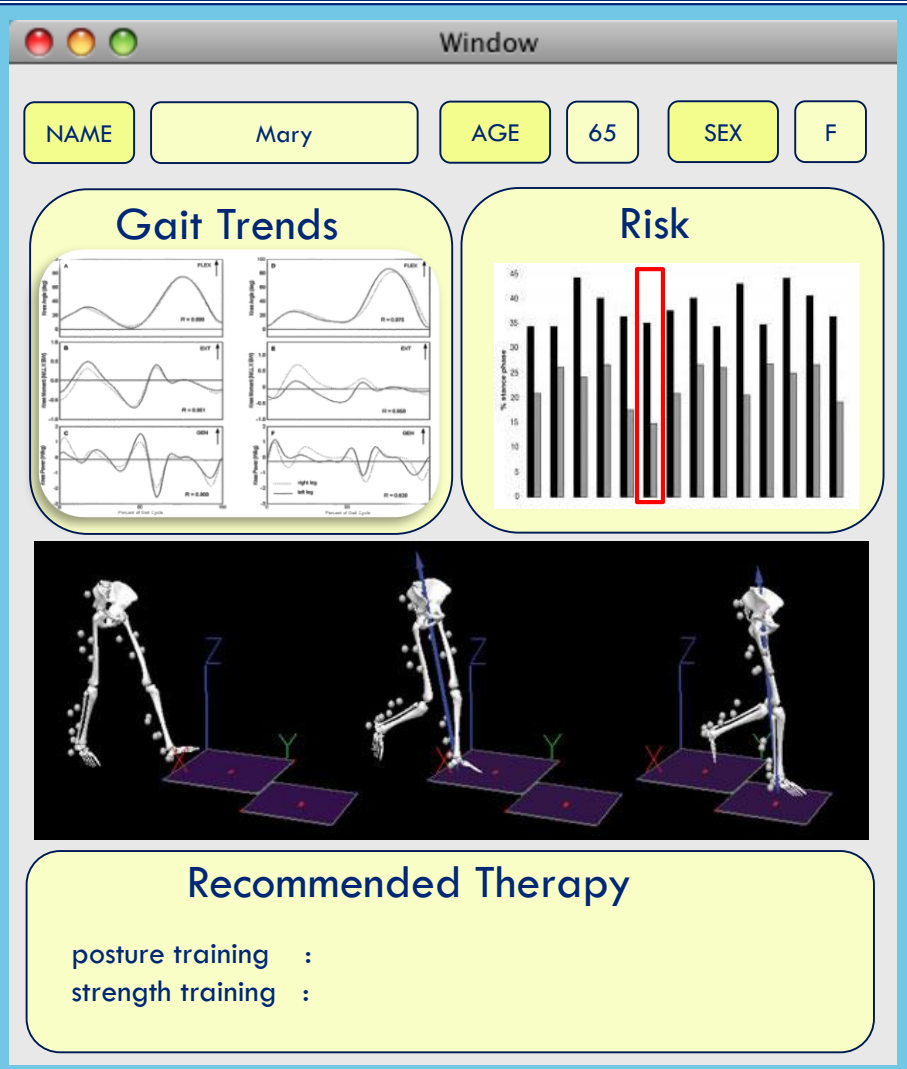
- 2,800 mAH (@ 25ma) 1.5v x 2 (series)
- Scenario 1: Firefly + Sparkfun 9DoF Razor IMU
  - Firefly node : 24.4 mA (Active + TX)
  - Sparkfun 9DoF Razor : 7.6 (Active)
    - Invensense MPU-9250 : 3.8 mA (Active)
    - Atmel SAMD21 : 3.64 mA (Active)
  - Total power : 32 mA (~4 days)
- Scenario 2: Firefly + 3-Space Embedded IMU
  - Firefly node : 24.4 mA (Active + TX)
  - 3-Space Embedded IMU: 45 mA (Active)
  - Total power : 70 mA (~1.5 days)

Appendix : Purchase List

- Items to be purchased
  - Box Fabrication ($0)
  - Straps (<$20)
  - IMUs*) ($50 x 4 + $140 x 2 = $480)
  - Battery (<$50)
  - Total : ~$550

Appendix : Use Case Example

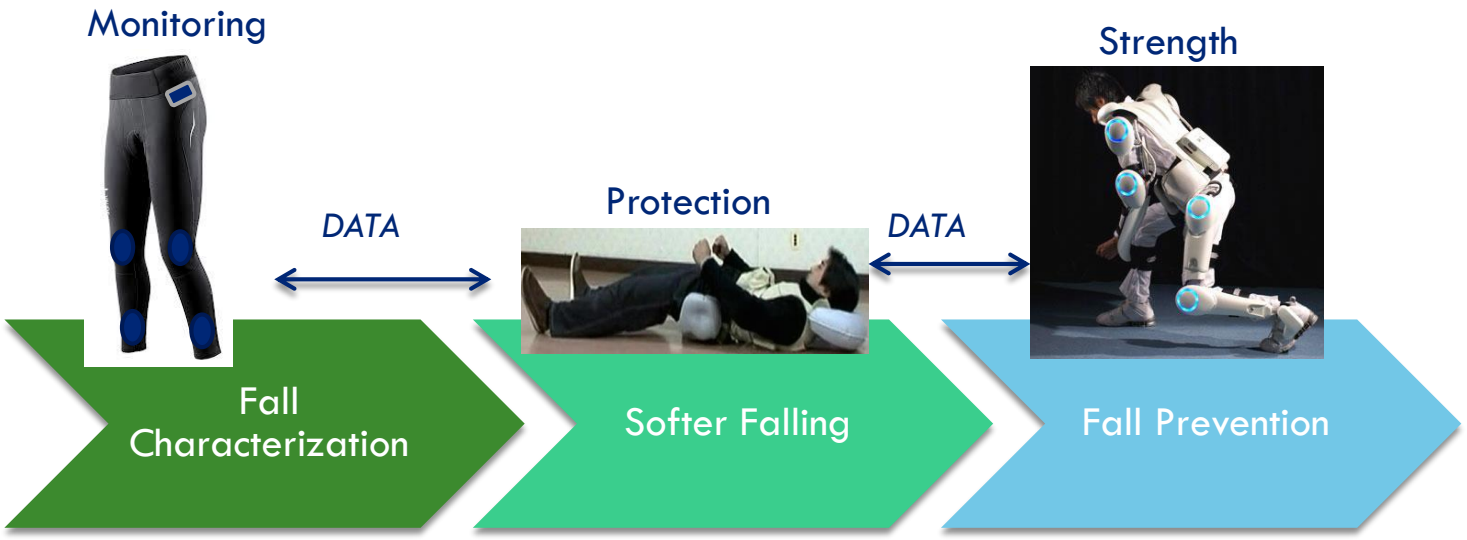




Appendix : Biz Model

	Product	Service	Brand
Stand			
Option		 	
Customization			    

Appendix : Biz Model



Appendix : Competitor

In-house monitoring solutions

Functional Electrical Simulation

Exoskeletons

Motion tracking systems