Smart Walker

Capstone Project Presentation and Demo

Presented by:
Junfeng Xian
Seung Yeong Park
Hongkyu Ahn
Andy Back

Outline

1. Company Background
2. Project Motivation
3. Business & Marketing
4. System Overview
5. System Specifications
6. Time & Budget
7. Future Work
8. Conclusion
9. Questions

Background of NBS^2

- 4 members

- Junfeng Xian (**CEO)**
- Seung Yeong Park (**Chief Marketing Officer**)
- Hongkyu Ahn (**Chief Technical Officer)**
- Andy Back (**Chief Information Office/CFO**)

Motivation of Smart Walker

"As we age, it is important to maintain as much independence as possible so we can still have maximum enjoyment from life" – insis.net

Motivation of Smart Walker

Source: NYTimes

Walker Safety Consideration

(Source: Medical Museion, University of Copenhagen)

1. "Lock" in open position but "Do Not" engage wheel locks while walker is moving
2. "Never" use walker as a wheelchair
3. "Do not" to overload the basket, as walker might lose the balance

(Source: Shoppers Home Health Care)

WALKER MARKETS

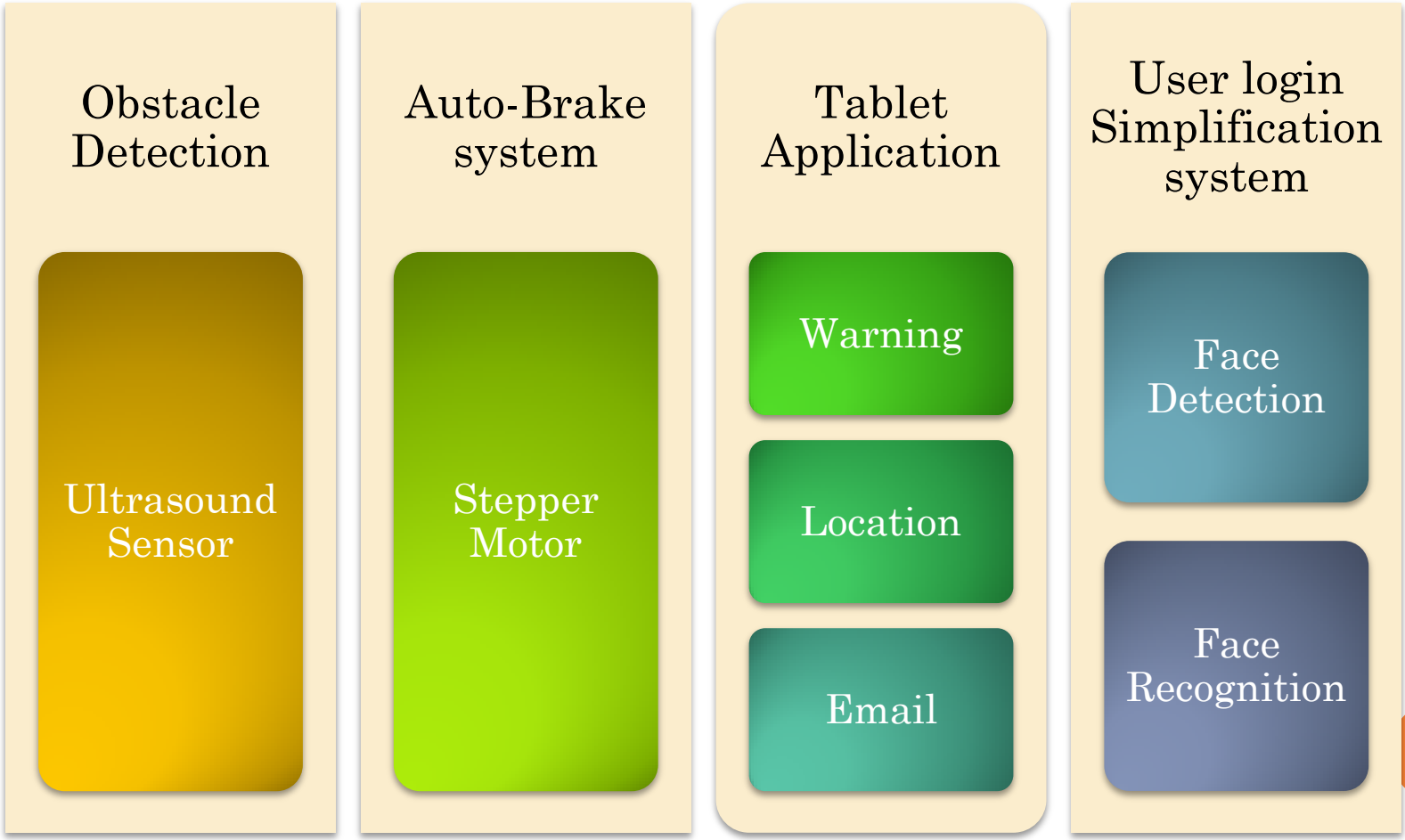
	Category A (Walkers with wheels)	Category B (Walkers without wheels)	Smart Walker from NBS[2]
Product Example			
Features	• Manual Brake/Lock • 4 Wheels • Height Adjustment	• No wheels • Height Adjustment	• All features from Category A • Extra obstacle detection feature • Location indicator • Scheduler • Auto email generator
Price Range	$199 ~ $499	$99 ~ $199	$199 ~ $499

System Overview

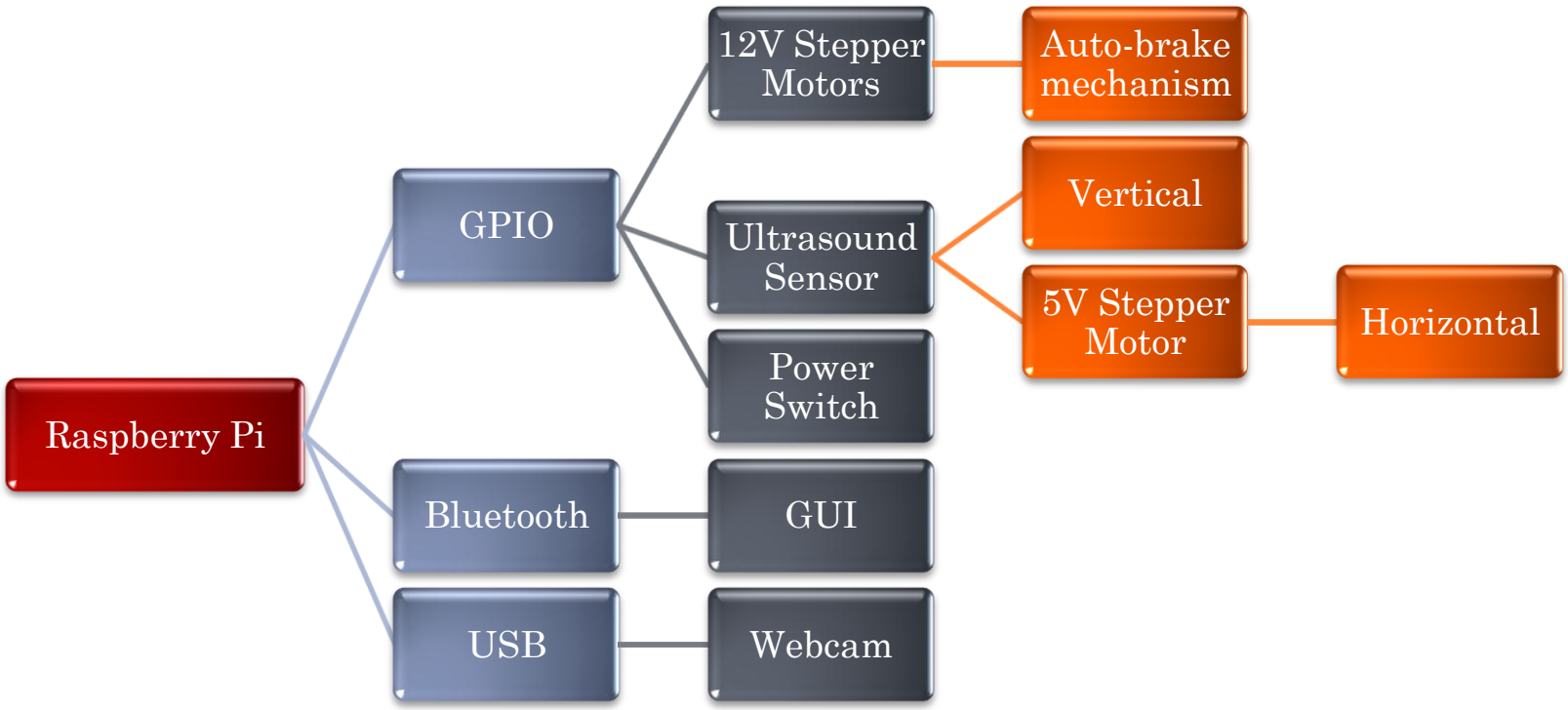
- Product main features
  - A walker with an extra safety feature
  - The location indicator
  - Auto-email generation for family member
- Target Customer
  - Elderly people with difficulty in mobility

Photo of Smart Walker

System Overview – Main functionality modules



System Overview – Block Diagram

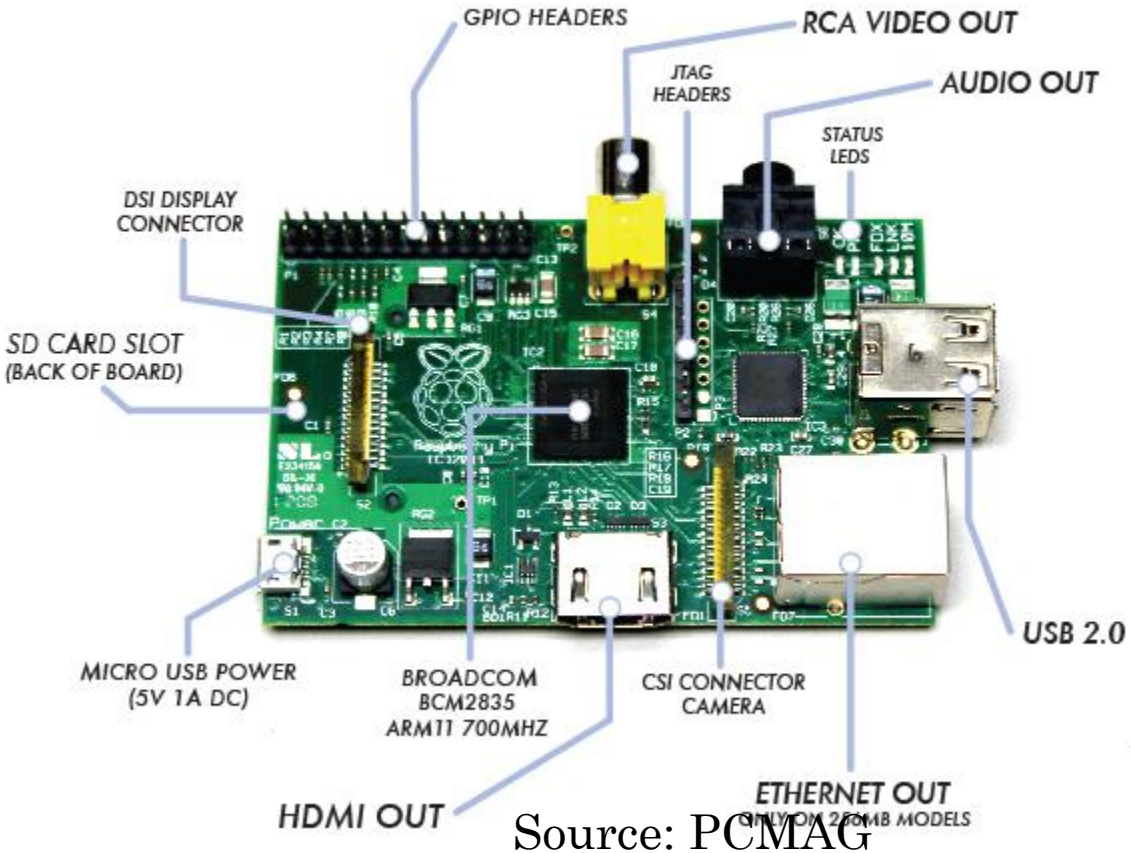


Design Choices

Name	Arduino Uno	Raspberry Pi	BeagleBone
Model Tested	R3	Model B	Rev A5
Price	$29.95	$35	$89
Size	2.95"x2.10"	3.37"x2.125"	3.4"x2.1"
Processor	ATMega 328	ARM11	ARM Cortex-A8
Clock Speed	16MHz	700MHz	700MHz
RAM	2KB	256MB	256MB
Flash	32KB	(SD Card)	4GB(microSD)
EEPROM	1KB		
Input Voltage	7-12v	5v	5v
Min Power	42mA (.3W)	700mA (3.5W)	170mA (.85W)
Digital GPIO	14	17	66
Analog Input	6 10-bit	N/A	7 12-bit
PWM	6		8
TWI/I2C	2	1	2
SPI	1	1	1
UART	1	1	5
Dev IDE	Arduino Tool	IDLE, Scratch, Squeak/Linux	Python, Scratch, Squeak, Cloud9/Linux
Ethernet	N/A	10/100	10/100
USB Master	N/A	2 USB 2.0	1 USB 2.0
Video Out	N/A	HDMI, Composite	N/A
Audio Output	N/A	HDMI, Analog	Analog

(Source: http://makezine.com)

Raspberry Pi



Source: PCMAG

Obstacle sensing

- Vertical

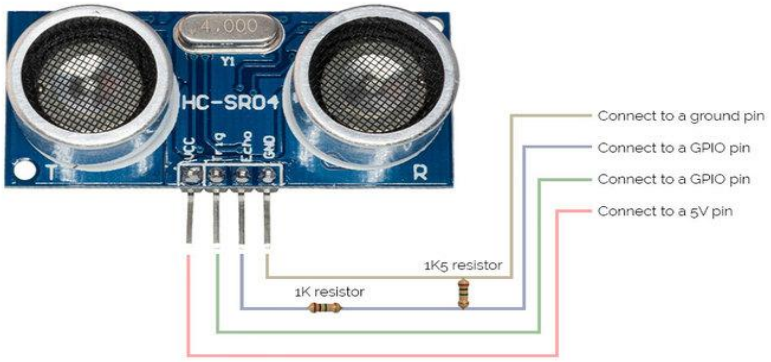
  - detect down-steps in front of the walker

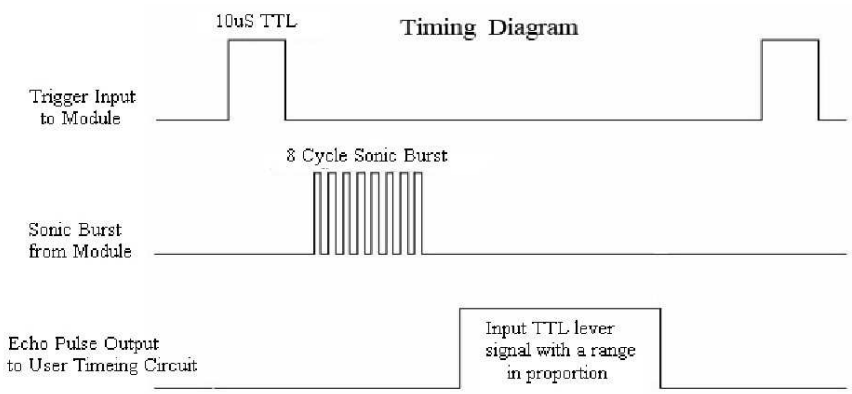
- Horizontal

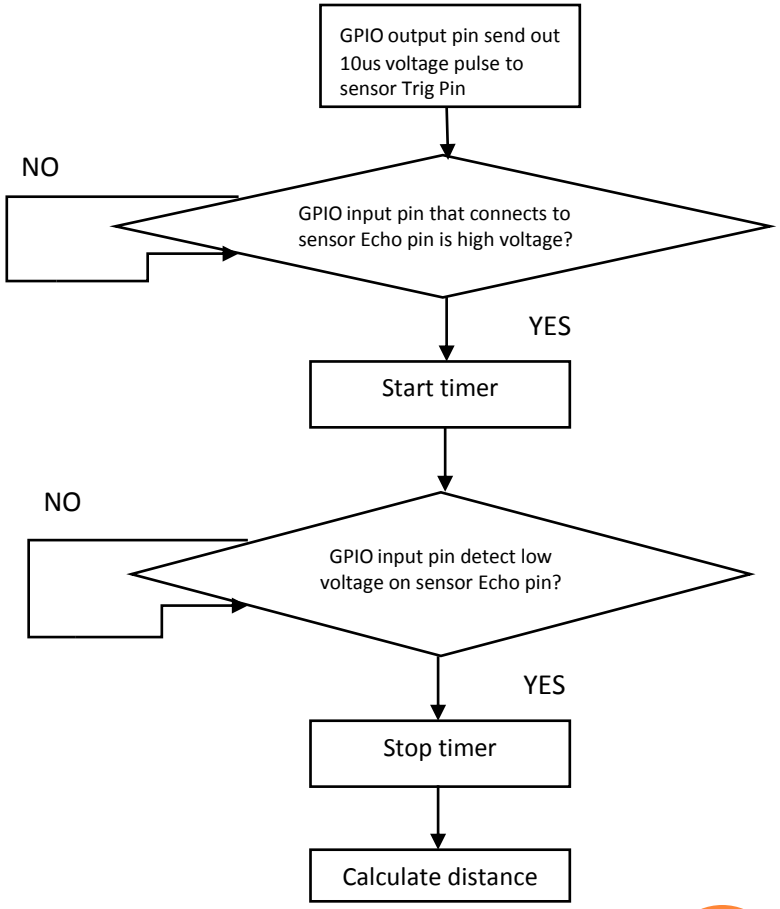
  - detect blocks and obstacles in front of the walker

Ultrasound Sensor

- Sensor controlling flow chart
- Sensor timing diagram



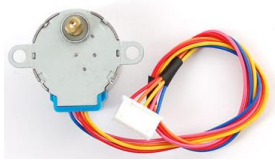




Motor and Sensor Mechanism

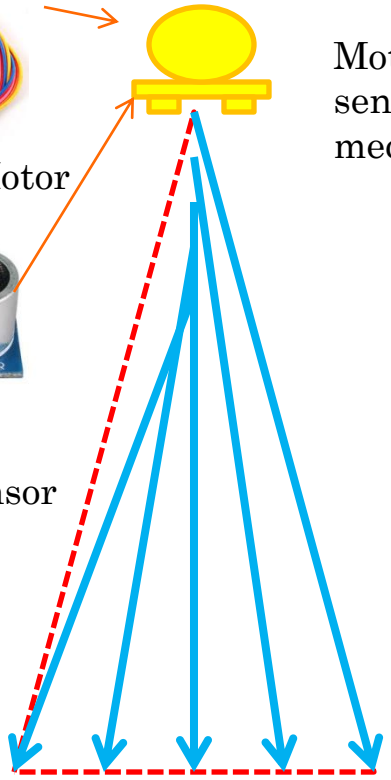
Horizontal distance sensor is attached to the shaft of motor for rotation

-To cover the wide range in the front



5V Stepper Motor

Ultrasonic Sensor



Motor and sensor mechanism

LINE SCANNING APPROACH

-Scan a line in 1 scan cycle

-Discretely scan pattern

-Speed of walker movement limits scanning quality

Warning # 1 – Auto-brake system

•Brake mechanism is controlled by motor on each side
•They are designed to apply brake gradually

Implementation

•Frictional brake with rubber pad at the contacting surface

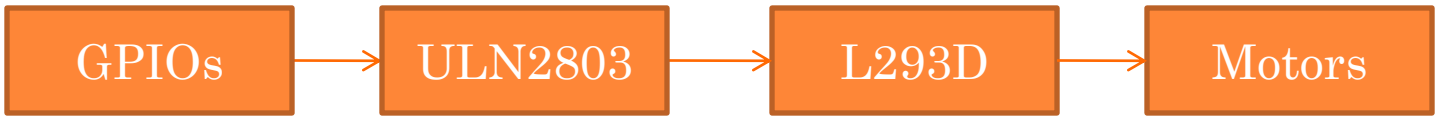
Stepper Motor

- 200 steps /rev, 12V, 350mA
- 2Kg*cm torque

Source:
Adafruit

- Controlled by the raspberry pi GPIO pin
- Powered by 8 AA batteries
- Forward and backup steps to apply and release the brake

Circuit



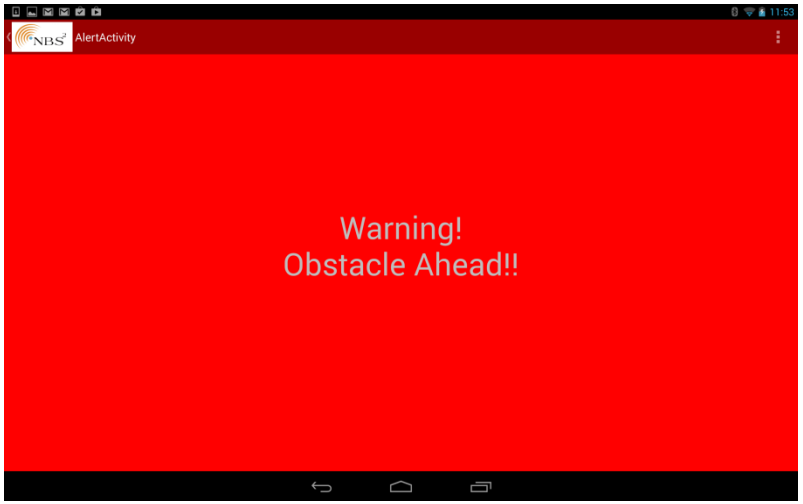
ULN2803 :Amplification/protection

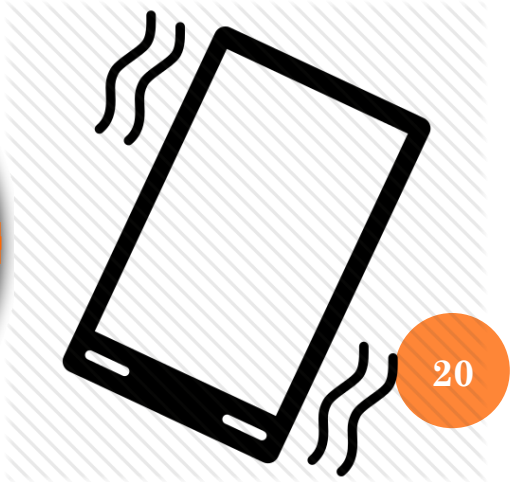
L293D :Amplification

4 outputs from L293 to motors

Warning #2 – Software Side

- Different types of warning
  - Visual warning
  - Audible warning
  - Physical warning





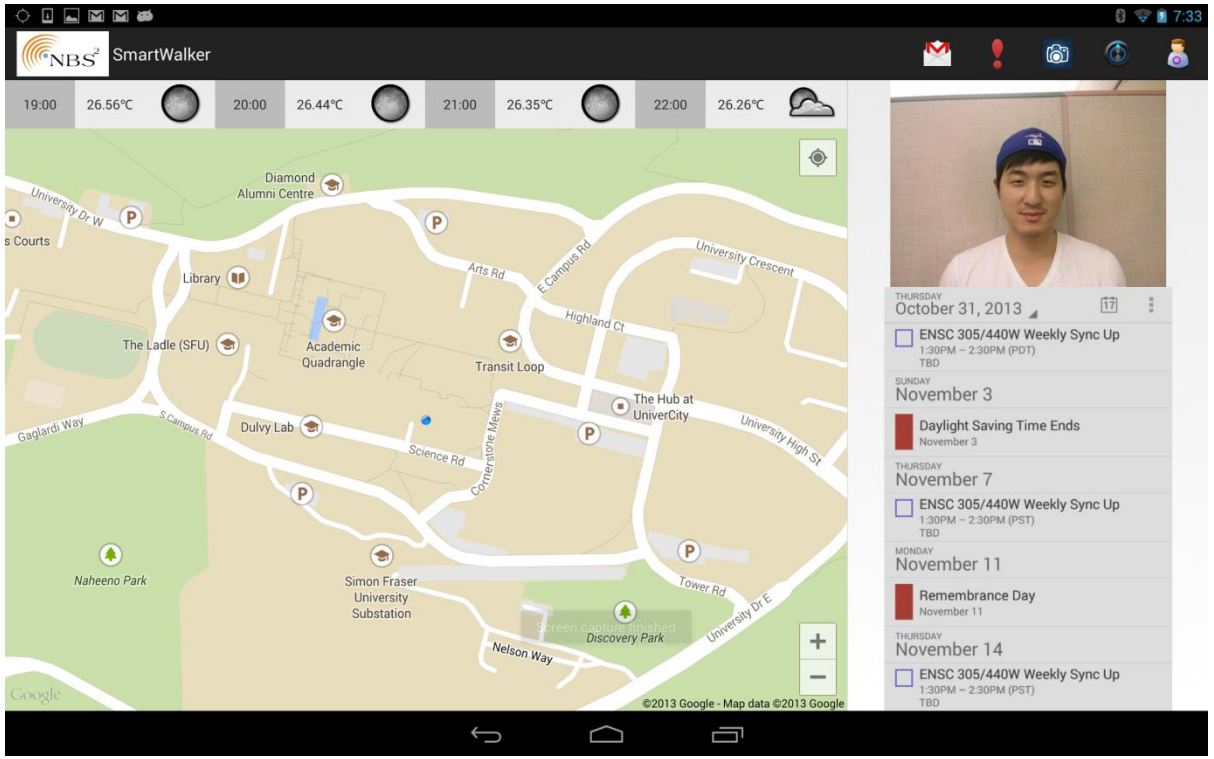
Android

- Most used smartphone operating system
  - 81% of the global smartphone shipment from last quarter*
- Open source
- Most devices cheaper than other products
  - Entry level Android phones ($200) vs iPhone 5c ($600) or iPhone4s ($450)
- No developer fee
- Only tablet we had was an Android device ☺

* http://news.cnet.com/8301-1035_3-57612057-94/android-dominates-81-percent-of-world-smartphone-market/

GUI

- No User Interaction while in use
- Personalized email and scheduler
- Location and Weather information



Module Testing

- Manual testing
  - Basic smoke test on actual devices (Nexus 10, Nexus 4)
  - UI button presses
  - Bluetooth connection with Raspberry Pi
- Automated testing
  - Google's UI Testing framework (UIAutomatorViewer) exists, but not used

User interface simplification

Objective:

- Simplify the login procedure for the personalized email and scheduler
- Consider target customers
- Power Save mode

Source: Logitech

Design Choices

	Fingerprint Sensor	QR Code	ID Card reader	NFC/RFID	Face Recognition
Usability	Difficult to use	Requires ID card with QR code printed	Requires ID card	Requires ID card	Might require ID card
Interface	USB	USB	USB	USB or UART	USB
Accuracy	Not possible with damaged fingerprints	Accuracy depends on a camera	Very Accurate	Very Accurate	Accuracy depends on a lightning condition
Design Cost	Very High (>$70)	Low (<$20)	High (~$50)	Medium (~$40)	Low (<$20)
ETC	Not suitable for our solution	Lack of familiarity among the elderly people Requires a reader software	Difficult to reproduce ID card	Difficult to reproduc e ID card	Easy to reproduce ID card

And Future development?

Face Detection & Face Recognition

- Open source OpenCV2 library under BSD license

Histogram Equalization + Color remapping

VS

Brightness Correction + Image Embossing filter

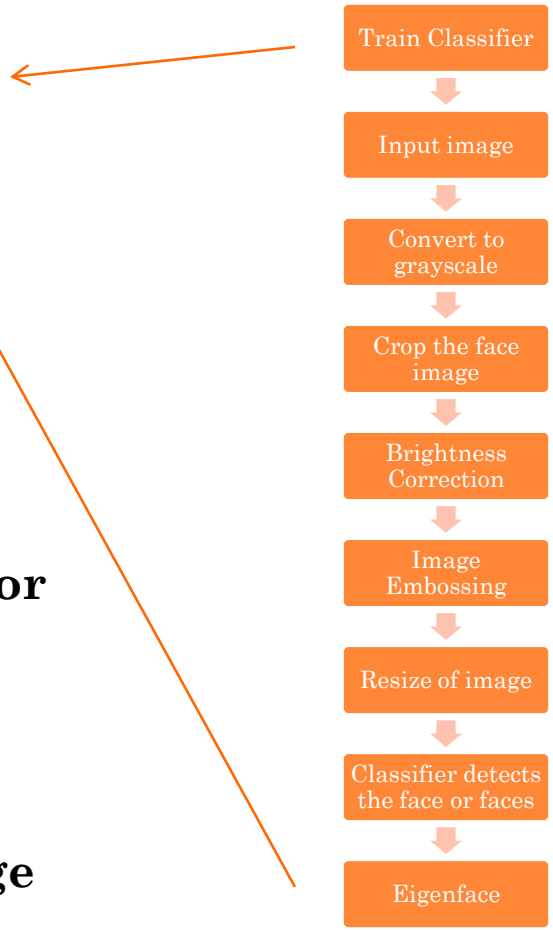


Image Cropping with face detection

Testing without pre-processing

Brightness = 22.50
Detected = No

Brightness = 36.16
Detected = No

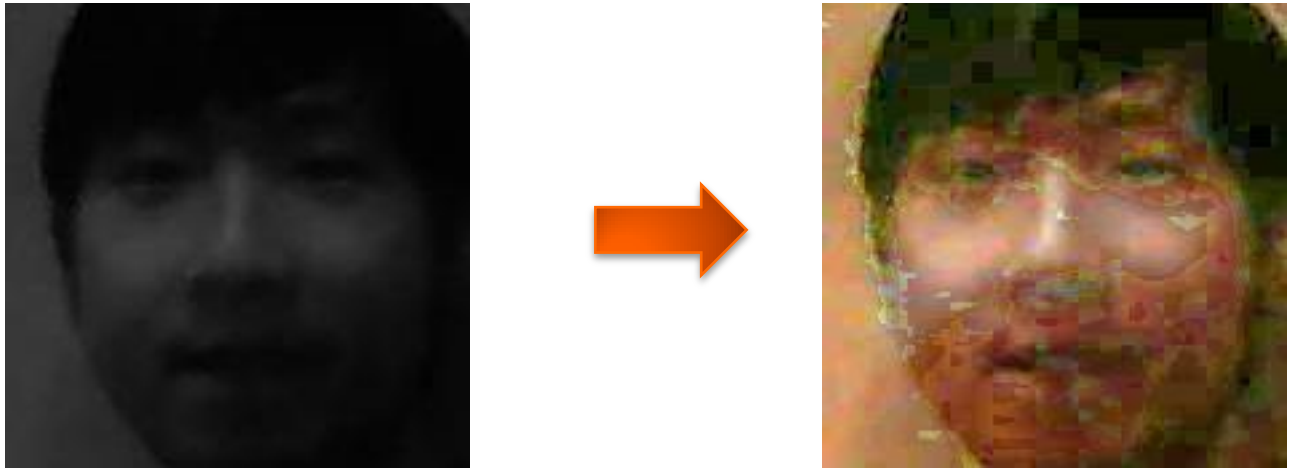
Brightness = 124.35
Detected = Yes
Recognized = Yes
Euclidean Distance = 4757

Histogram Equalization and Color Remapping

"Nonlinear Image Enhancement to Improve Face Detection in Complex Lighting Environment" - Li Tao, Ming-Jung Seow and Vijayan K. Asari

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.121.9856&rep=rep1&type=pdf

Histogram Equalization and Color Remapping



- Processing time: ~3 minutes
- Noisy

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.121.9856&rep=rep1&type=pdf

Brightness Adjustment

Brightness = 22.50
Detected = No

Brightness = 73.16
Detected = Yes
Recognized = Yes
Euclidean Distance = 4825.6

Embossing filter

$$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 1 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

Overall

- Results depend on the lightening conditions
- Due to the limitation of Eigenface algorithm, the face recognition becomes worse in a dark environment -> Warning pops up on an Android App

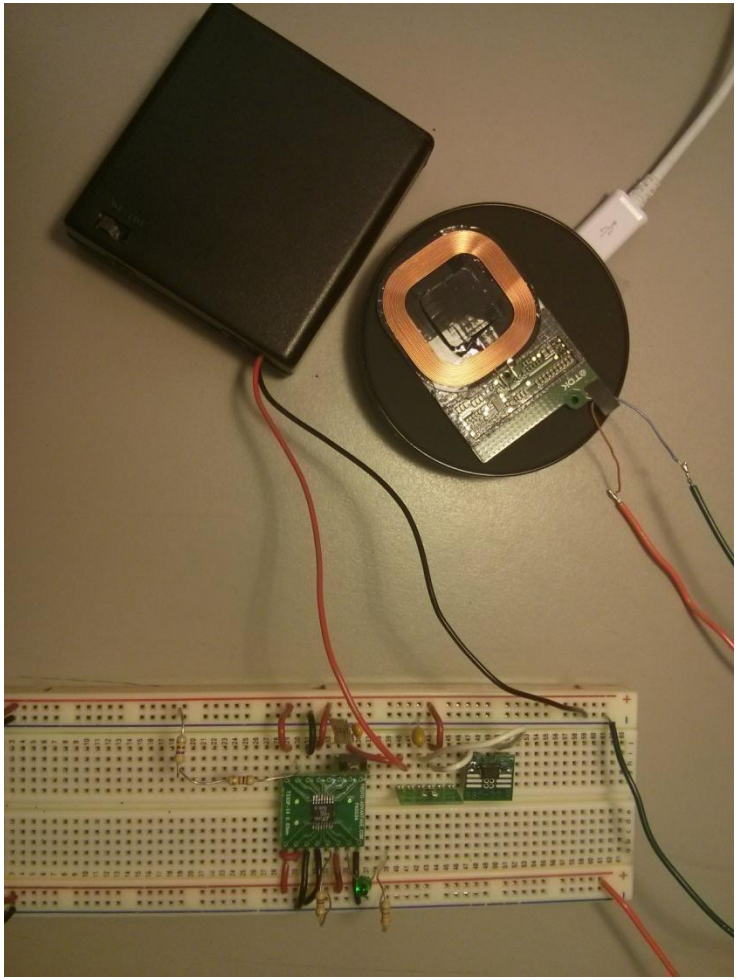
Power Consumption

System	Battery type	Voltage	Capacity (mA)	Estimated Battery life (hours) (1)	Features
Raspberry Pi	5V Li-Ion Battery Pack	5V (regulated)	4400	6.3	Chargeable
12V stepper Motor	1.2V AA NiMH Battery (8 of them in series)	9.6V	2450	7	Chargeable, Replaceable
5V stepper Motor	1.2V AA NiMH Battery (4 of them in series)	5V	2450	27	Chargeable, Replaceable

(1) Please note that the actual battery life might be longer since we made an estimation based on the maximum current consumption.

Charging solution (Proof of Concept)

- Easy to charge
- Wireless Charging
- Qi Standard (WPC)



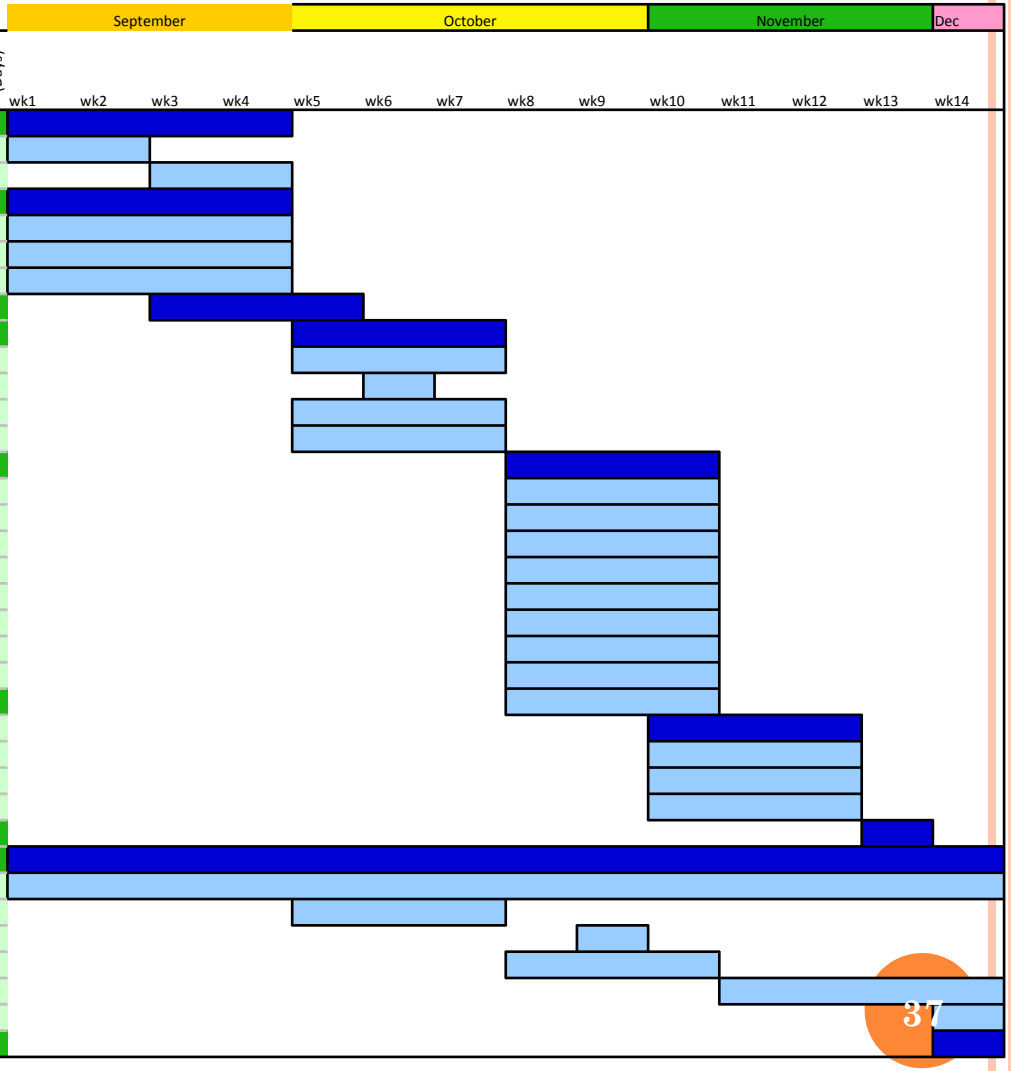
Schedule

- Delays on schedule
  - Change in topics (1st week of October)
  - Late arrival for ordered parts
  - Parts not functioning suddenly -> Late integration
- Difficulties
  - Change in topics
  - Full course load for all team members

SCHEDULE (CONT'D)

Start Date: September 3, 2013 Tuesday

WBS	Tasks	Task Lead	Start	End	Duration (Days)
1	**Topic selection and project proposal**	Junfeng Xian	9/3/13	9/26/13	24
1.1	Topic selection		9/3/13	9/16/13	14
1.2	project proposal		9/17/13	9/26/13	10
2	**Research and functional Specification**	Junfeng Xian	9/3/13	9/30/13	28
2.1	NFC, BT concepts and modules selection		9/3/13	9/30/13	28
2.2	Android app programming		9/3/13	9/30/13	28
2.3	Power supply and wireless charger circuit		9/3/13	9/30/13	28
3	**Project funding and parts ordering**	Junfeng Xian	9/16/13	10/5/13	20
4	**Project design**	Seung Yeong Park	9/27/13	10/10/13	14
4.1	BT and NFC firmware combiation	Junfeng Xian	9/27/13	10/10/13	14
4.2	Hard drive selection	Hongkyu Ahn	10/7/13	10/10/13	4
4.3	Power supply and wireless charger design	Seung Yeong Park	9/27/13	10/10/13	14
4.4	Android app design	Andy Back	9/27/13	10/10/13	14
5	**Project Topic Shfiting - Smart Walker**	Junfeng Xian	10/10/13	10/31/13	22
5.1	Quick research on Smart Walker	Junfeng Xian	10/10/13	10/11/13	2
5.2	System overview and functionalities specifications	Seung Yeong Park	10/12/13	10/13/13	2
5.3	Order new parts and components and tasks assignment	Junfeng Xian	10/14/13	10/14/13	1
5.4	Ultrasoninc sensor design and communication with Raspberry Pi	Junfeng Xian	10/15/13	10/31/13	17
5.5	Auto brake system design and communication with Raspberry Pi	Hongkyu Ahn	10/15/13	10/31/13	17
5.6	Motor, camera and Raspberry Pi connection codings	Seung Yeong Park	10/15/13	10/19/13	5
5.7	Wireless charging circuit design	Seung Yeong Park	10/20/13	10/31/13	12
5.8	user interface design	Andy Back	10/15/13	10/31/13	17
6	**Project integration**	Seung Yeong Park	11/1/13	11/17/13	17
6.1	integration with brake system and walker attachment solutions	Hongkyu Ahn	11/1/13	11/17/13	17
6.2	integration with sensors, camera and switches	Junfeng Xian	11/1/13	11/17/13	17
6.3	Wireless charging circuit design and camera usage designs	Seung Yeong Park	11/1/13	11/17/13	17
6.4	User requirement survey and Android user interface design	Andy Back	11/1/13	11/17/13	17
7	**Project testing and verification**	Hongkyu Ahn	11/18/13	11/27/13	10
8	**Project documentation**	Andy Back	9/3/13	12/2/13	91
8.1	Lab journal, meeting minutes, Canvus discussion	Andy Back	9/3/13	12/2/13	91
8.2	Functional specification	Andy Back	10/1/13	10/17/13	17
8.3	Oral progress report	Andy Back	10/25/13	10/31/13	7
8.4	Design specification	Andy Back	10/18/13	11/7/13	21
8.5	Progress report	Andy Back	11/8/13	12/2/13	25
8.6	Post-mortem	Andy Back	11/29/13	12/2/13	4
9	**Project demo, presentation and final report**	Junfeng Xian	11/28/13	12/2/13	5



Development & Production Costs

Income			
Grant from ESSS	$250		
		Total	$250
Expense			
Raspberry Pi (x2)	$130	Web cam	$12
Bluetooth Dongle (x2)	$40	Rechargeable Batteries (x12)	$45
Used walker	$50	Acryl	$50
SD card	$25	Battery Pack	$50
Wireless charger/circuit components	$80	Parts (screws, wood, etc)	$40
Wireless charger transmitter	$55	Sensors (x2)	$30
Motors	$30		
		Total	$697
Total			
$250 - $697		Total	-$447

- Proposed cost for prototype was $400
- Extra cost of $297 incurred due to the change in topics
- Were able to re-use most parts that were already ordered

Business Consideration

- Survey Results
  - Total number of participants: 14
  - Most elders were reluctant to any changes
  - On a bright side, more than 50% of elders in 60s were fairly comfortable with smartphones

Future Development

- Different audience target
  - Young moms with baby stroller
- App Support on other platforms
  - iOS
  - Windows Phone
  - BB10
- Use less power consuming Microcontroller
  - Can support stronger motor
- Add another motor on front wheel
  - Can be used to steer wheel to change directions

Comparison functional spec and design spec

- ***Improve*** sensor systems by adding sensor-motor mechanism on horizontal detection
- ***Increase*** the torque of brake motor by using 12V stepper motors
- ***Integrate*** auto-email feature in the user interface application
- ***Implement*** face recognition and face detection functions in the system

Conclusion

- Great learning experience
  - project management skills
  - cover most critical ENSC courses
- Great teamwork
  - help each other to solve problems
  - motivate each other
  - share ideas

Individual Contributions

JUNFENG XIAN

Responsibility (CEO)

- Assign tasks to group members
- Organize team activities and team meetings
- Develop obstacle detection module and main program on Raspberry Pi

Activities

- Raspberry Pi GPIO configuration
- Sensor selection
- Ultrasonic sensor and Raspberry Pi integration
- Sensor detection algorithm
- System integration
- System testing related to micro-controller and sensors

Correlated to specific knowledge in ENSC courses

- ENSC 351 – multi-thread programming
- ENSC 387 – sensors and actuators
- ENSC 489 – SolidWorks modeling

Hongkyu Ahn

Technical

- Brake mechanism to be work with motors
- Frame and wood work, mounting components
- Software to configure forward steps and backward steps for motor
- Amplifying circuit

Activities

- Research, ordering and picking up parts/materials
- Failed a couple of brake mechanism
- Required extensive iterative/repetitive testing for brake mechanism

Correlated to specific knowledge in ENSC courses

ENSC 220, ENSC 351(programming part), ENSC 489,

Seung Yeong Park

Technical

- Face detection for enabling power saving mode
- Face recognition for user interface simplification
- Early version of motor control script
- Qi Wireless Charging circuit as for the proof of concept

Activities

- Motor code integration by enabling a thread from the early version of main code
- System integration and testing related to face recognition/detection
- Overall system integration on Raspberry Pi / Circuit to provide a protection to GPIO
- Choosing the IC chips for motor circuit and wireless charging circuit
- Wireless Charging circuit testing

Correlated to specific knowledge in ENSC courses

- ENSC 351 – multi-thread programming on Linux
- ENSC 424 – image processing (image convolution, histogram equalization)
- ENSC 220 – fundamentals of electronics

Andy Back

Responsibility (CIO, CFO)

Technical

- Android app development using Java
- Raspberry Pi Bluetooth communication

Activities

- Android app development (Bluetooth, Google Maps, Email)
- Responsible for all the meeting minutes
- Market research (survey)

Correlated to specific knowledge in ENSC courses

ENSC 351 – Multi-threaded Programming
ENSC 488 – Coding experience
ENSC 427 – Communication System (for Bluetooth)

Demo

Questions

Acknowledgement

- Mr. Lucky One
- Mr. Mike Sjoerdsma
- Mr. Lukas-Karim Merhi
- Ms. Mona Rahbar
- Mr. Ali Rahbar
- Mr. Jamal Bahari

References

- [1] NBS2 Solutions Inc., "Functional Specification for Smart Walker System", Simon Fraser University, Burnaby, BC, Canada, Oct 13 2013.
- [2] Toshiba, ULN2803A *8ch Darlington Sink Driver,* 2010. [Online] Available: http://www.adafruit.com/datasheets/ULN2803A.pdf [Accessed: Nov 6, 2013].
- [3] Logitech, "Webcam C210 Support", date unknown. [Online] Availble: http://www.logitech.com/en-us/support/webcam-c210 [Accessed: Nov 2, 2013].
- [4] Linear Technology, LTC4060 *Standalone Linear NiMH/NiCd Fast Battery Charger Datasheet*, 2012. [Online] Available: http://cds.linear.com/docs/en/datasheet/4060f.pdf [Accessed: Nov 2, 2013].
- [5] Wireless Power Consortium, "Wireless Power Technology", date unknown. [Online] Available: http://www.wirelesspowerconsortium.com/technology [Accessed: Nov 4, 2013]. QI charging reference
- [6] Intel Corporation, "OpenCV 2.4.7.0 documentation", OpenCV, date unknown. [Online] Avaiable: http://docs.opencv.org/index.html [Accessed: Oct 30, 2013].
- [7] P. Wilson and J. Fernandez, Facial Feature Detection Using Haar Classifiers, the Consortium for Computing Sciences in Colleges, Texas, 2006. Available: http://nichol.as/papers/Wilson/Facial%20feature%20detection%20using%20Haar.pdf [Accessed: Oct 29, 2013].
- [8] M. Turk and A. Pentland, Eigenfaces for Recognition. *Journal of Cognitive Neuroscience,* 3 (1), 1991a. Available: http://www.cs.ucsb.edu/~mturk/Papers/jcn.pdf [Accessed: Oct 18, 2013].
- [9] A. Martines, "Fisherfaces", Ohio State University, Ohio, 2011. [Online] Available: http://www.scholarpedia.org/article/Fisherfaces [Accessed: Nov 9, 2013].
- [10] Elec Freaks, HC-SR04 *Ultrasonic Raging Module datasheet,* date unknown. [Online] Available: http://elecfreaks.com/store/download/HC-SR04.pdf [Accessed: Oct 10, 2013].

Thank You