PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Daniele Gatti

XXXII Cycle

Training and Research Activities Report – First Year

Tutor: Prof. Pasquale Arpaia

1. Information

a. PhD Candidate: Daniele Gatti Master's degree in Electronic Engineering (cum laude), University of Naples Federico II

b. Doctoral Cycle: XXXII Cycle- ITEE – Università di Napoli Federico II

c. Fellowship type: Programma Operativo Nazionale (PON)

d. Tutor: Prof. Pasquale Arpaia

2. Study and Training activities

a. Courses

- Ad hoc Course: "*Designing and realizing complex experiments: a case study on SPS experiments to test crystal collimation for LHC"* Prof. Walter Scandale – Naples from 6/06/17/ to 13/06/17, 3 CFU.
- MSc Course: "*Misure su reti di comunicazioni*", Prof. Pasquale Arpaia, Naples 11/07/2017, 6 CFU.
- MSc Course: "*System On Chip*", Prof. Nicola Petra, Naples 19/01/2018, 9 CFU.
- PhD School: "*Italo Gorini 2017 Doctoral Summer School*" promoted by the Italian "Electrical and Electronic Measurement" (GMEE) and "Mechanical and Thermal Measurement" (MMT) associations, Catania, August 28st – September 1th, 2017, 3 CFU.

b. Seminars

- "*How to organize and write a scientific rebuttal*" organized by Prof. Pasquale Arpaia 10/03/17, 0.5 CFU.
- "*Superconduttività: opportunità di sviluppo e di trasferimento tecnologico*" organized by Prof. Piero Salatino 29/03/17, 0.5 CFU.
- "*From mathematical formalization to artificial visual-attention: toward a human-like robot vision"*, Prof. Kurosh Madani 4/04/17, 0.4 CFU.
- "*Framework tools for visual sensor interfacing*" organized by Prof. Pasquale Arpaia and, Prof. Leopoldo Angrisani, 8/05/17, 0.5 CFU.
- "*LabVIEW Core2*", (14 Hours) from 16/05/17 to 17/05/2017, 2.8 CFU.
- "*Data Acquisition and Signal Conditioning"*, (14 Hours) from 18/05/17 to 19/05/2017, 2.8 CFU.
- "*Interfaces based on immersive life-size augmented environments for advanced monitoring system*" organized by Prof. Pasquale Arpaia and, Prof. Leopoldo Angrisani– 30/05/17, 0.5 CFU.

- "*Innovative design and Material Processing for Additive manufacturing*", Prof. Piero Salatino-26/01/2018 0.6 CFU.

CS Summary

Student: Daniele Gatti									Tutor: Pasquale Arpaia									Cycle XXXII									
daniele.gatti@unina.it									pasquale.arpaia@unina.it																		
	Credits year 1								Credits year 2									Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	18			9	3		9	21	15							0								0	21	30-70
Seminars	13	1	7			0	0.6	8.6	5							0								0	8.6	10-30
Research	34	4.5	4.5	5.4	6.5	5.5	4	30	40							0								0	30	80-140
	65	5.5	12	14	9.5	5.5	14	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	180

3. Research activity

a. Title

Low-cost indoor positioning and tracking measurements system for augmented reality.

b. Study

The research concerns the use of low-cost transducers based on microcontrollers to precisely define the motion of humans or objects in an immersive environment of augmented reality for serious games.
The most important characteristics of a localization system are the accuracy and the latency. Usually, the accuracy range in indoor localization application varies from 1 m to sub-centimetre range. For augmented reality application, the accuracy range varies from 1 mm to 10 cm.
Many researchers try to use a localization system for outdoor in an indoor application, but the localization error is more than 1 m.
Various techniques and technologies are used in order to solve the indoor tracking problem but, the fundamental of localization is based on a preliminary ranging of reference fixed beacon node and a further continuous relative distance measurement between the beacons and the localizing target.
The distance between the beacons and the localizing target combined by localization algorithms allowed the target position.
The most common positioning algorithms are the triangulation and trilateration. The triangulation uses measured angles to calculate the coordinates of an unknown position target, while the trilateration uses measured distances from beacons to unknown position target.

In the first phase of my research, I have identified the main technologies used in the indoor location that is: radio frequency, camera-based solution, infrared and ultrasonic [1].
Usually, the technique used in the radio frequency location is the Received Signal Strength Indicator measurements. Thanks to a path-loss model, the distance can be obtained. Even ultra-wideband signals combined with time differential of arrival are often used for radio frequency localization. A relatively recent technology that is based on power or tomography measurements uses the RFID. The radio frequency solutions are difficult to use in augmented reality applications because a few centimeter accuracy and 15 ms latencies are required.
The camera-based solution typically uses RGB camera to extract the cues and comparison of consecutive frames or using an infrared depth camera to localize marker. This solution is less accurate for precise tracking application.

Typically, the infrared technology uses the phase difference measurements or using infrared camera to localize markers. The best solution in terms of latency and accuracy is offer by the infrared camera combined with infrared reflective markers. The markers are beamed with IR light and reflect this light back into the directions of the IR cameras. Using 3D-reconstruction model based on the camera features, the orientation and position of tracking targets can be obtained. Thanks to the high refresh rate camera, low latencies (1 ms) can be reached. Unfortunately, all of this is at the expense of a high cost of the System.

Ultrasonic locations system is based on the time differential of arrival or times of flight measurements. Often for the time of flight measurements, a radio frequency signals are combined with ultrasonic.
The time differential of arrival technique measures the times of arrival of signals propagating at a known speed. The signal time differential of arrival is related to the target position because the signal speed is constant. The time of flight consists of sending an ultrasonic burst from the transmitter and measuring the time elapsed to receive the echo signal. In my opinion, the ultrasonic solution is the best compromise price/performance in terms of accuracy and latency.

c. Research description

A proof-of-principle demonstrator based on ultrasonic technology capable of identifying the beacon node in low time is implemented [2]. Time differential of arrival is measured by a microcontroller (Nucleo STM32L152RE) combined with a custom receiving circuit. The position is computed using a personal computer after the demonstrator acquisition. The demonstrator is validated by static 2D position measurements using two synchronized emitting beacon nodes.

For the proof-of-principle demonstrator, only two beacons are used, because the aim of this work is to demonstrate the recognition of different beacon in a low time. The recognition algorithm is very simple, different beacons are recognized by comparing the received signal with a threshold: when the signal is greater than the threshold, a counter is incremented. If the signal is observed in a fixed time window, the counter value depends only on the time shape of the received signal. The beacons node are driven by a sinusoidal signal; thereby, if different signal frequencies are emitted by the beacons, the counted value at the receiving node is different.
The main blocks of the receiver node are: the microcontroller Nucleo STM32 L152RE, the ultrasonic sensor SensComp's Series 9000, and a custom sensor-microcontroller interface circuits.
The custom interface circuit includes three stages: damping circuit, analog amplifier stage, and a square circuit stage. The damping circuit is composed by a one-channel optoisolator, connected in parallel to the ultrasonic receiver. When the optoisolator is activated, the damping time is reduced thanks to the low resistance offered by the optoisolotar, which forces the sensor in a steady state. The analog amplifier stage is composed by a dual operational amplifier in single-supply mode in order to amplify and filter the small-amplitude output signal from the receiver. The scope of the comparator circuit is to convert the threshold passage of the received signal in a pulse. Finally, the comparator output is connected to the microcontroller in order to: count the number of threshold passages, recognize the node, and measure the time differential of arrival.

As next step in my research activity is focused on the validation of tracking robotic systems interventions in harsh environments in the augmented reality labs at CERN and modeling of the motion and the synthesis of virtual agents to improve the human interaction with him.

4. Products

a. Publications

[1] Leopoldo Angrisani, Pasquale Arpaia, and Daniele Gatti. "*Analysis of localization technologies for indoor environment.*" IEEE International Workshop on Measurement and Networking (M&N), 2017.

[2] Leopoldo Angrisani, Pasquale Arpaia, and Daniele Gatti. "*Fast beacon recognition for accurate ultrasonic indoor positioning*." IEEE International Workshop on Measurement and Networking (M&N), 2017.

5. Conferences and Seminars

a. IEEE International Workshop on Measurements and Networking, 27-29 September 2017, University of Napoli Federico II Naples, Italy.
Presentations made: "*Fast beacon recognition for accurate ultrasonic indoor positioning*",

b. NeaPolis Innovation Technology Day, Wednesday 13 November 2017 STMicroelectronics Via Remo De Feo 1, Arzano (NA).

6. Activity abroad

I haven't spent time abroad during the first year PhD course.

7. Tutorship

I did a tutorship activity for bachelor degree thesis with my tutor Prof. Pasquale Aprai and Eng. Umberto Cesaro for the student Marco Speranza from Information and Technology Electronics Engineering bachelor degree. The title is "MISURA DI POSIZIONE INDOOR MEDIANTE MULTILATERAZIONE SU MICROCONTROLLORE NUCLEO STM32L152RE".