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 – Second 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: No fellowship

d. Tutor: Prof. Pasquale Arpaia

2. Study and Training activities

a. Courses

For this year I haven' t follows any courses because I spend time aboard, I suppose to take 9 modules credits the third year in order to reach 30 totals credits.

b. Seminars

For this year I haven' t follows any seminars because I spend time aboard, I suppose to take 2 seminary credits the third year in order to reach 10.3 totals credits.

CS Summary

Student: Name Surname				Tutor: Name Surname						Cycle XXXII																	
daniele.gatti@unina.it				pasquale.arpaia@unina.it																							
	Credits year 1								Credits year 2								Credits year 3										
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6				
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	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	9	7.5	7.5	7	6	8	45								0	75	80-140	
	65	5.5	12	14	9.5	5.5	14	60	60	9	7.5	7.5	7	6	8	45	0	0	0	0	0	0	0	0	105	180	

3. Research activity

a. Title

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

b. Study

My second year has been based on continuous of the first, in particular using the ultrasonic technology and low-cost sensor fusion for the indoor localization problem. The objective of the research concerns to use low-cost electronics in order to define the motion of humans or objects in an immersive environment of augmented reality scenario.
The main characteristics of a localization system are the accuracy and the latency. The accuracy range in indoor localization application varies from 1 m to sub-centimetre range. For augmented reality application, the required accuracy range varies from 1 mm to 10 cm.

The 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 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.

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 a 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.

Thanks to my experience with the ultrasonic system from the first year I decided to combine the ultrasonic system whit the ultra-wideband. I studied a way to fuse the information from both systems, using the ultrasonic technology for the heading measurement and the ultra-wideband for the distance measurements.
The trilateration algorithm can be implemented whit an Extended Kalman Filter in order to get the position; the phase difference on two or more ultrasonic receiver can be used for the heading. The Extended Kalman Filter offers good performance when noise is present in the distance measurements for this reason, I decide to use this filter.
The zero crossing phase difference measurements technique offer bad performance when noise is present at the received signal, for this reason, I

decided to explore the application of three parameters sine-fit algorithm to extract the phase difference of the ultrasonic received signal.

c. Research description

First I made a simulation of the trilateration system using the Extended Kalman Filter. The estimated state of the EKF is the target 2D position, while the measured distance between the reference fixed node and the target node are the inputs. The aim of the simulation is to test the theoretical performance considering 10 cm of accuracy for the distance measurements. The mean position difference between the theoretical position and the filter output is about $\varepsilon = 7$ cm with a $\sigma = 5$ cm of standard deviation.

A new approach based on ultrasonic and ultra-wideband fusing is investigated. The orientation (heading) of target respect to the reference frame, can be computed using the position of the target frame came from the ultra-wideband system and the phase difference measurement by a couple of ultrasonic receivers [1]. The phase difference is extract using the three-parameter sine-fit.

I made a simulation in order to test the performance of this approach. For the received signal, the damped sinusoid model with an SNR = 30 dB is assumed. The mean difference between the real angle and the estimated is about $\varepsilon = 1.9°$ whit a $\sigma = 1.5°$ standard deviation.

The next step in my research activity is on the validation of the simulation data whit the real system for the ultrasonic and the ultra-wideband. Currently, I made the ultra-wideband system using the decaWave DW 1000 module, the STM32F401 and the STM32F303K8T6 ST microcontroller.

Products

d. Publications

[1] Angrisani, L., Arpaia, P., Gatti, D., Masi, A., & Di Castro, M. (2018, August). Augmented Reality monitoring of robot-assisted intervention in harsh environments at CERN. In *Journal of Physics Conference Series* (Vol. 1065, No. 17).

4. Conferences and Seminars

a. XXII World Congress of the International Measurement Confederation (IMEKO), 3-6 September 2018 Belfast (UK).
Poster made: "*Augmented Reality monitoring of robot-assisted intervention in harsh environments at CERN*",

5. Activity abroad

I spent six months at CERN Geneva at the robotics team. I develop an architecture of human-robot navigation system, based on ultra-wideband decaWave DW 1000 module, the STM32F401, the STM32F303K8T6 microcontroller and the Sony SmartEyeglass AR glasses. The main idea is to send a robot for inspection in potentially dangerous areas and to guide personnel in this environment in order to guarantee their safety.
The main monitored environmental parameters are the level of radioactivity, the oxygen level percentage and the temperature. The robot must precede the human, measure the environment and guide the operator ensuring that it is always at a safe distance. The measurements performed by the robot must be shown to the user through AR glasses. For that activity, I develop the 2D positioning system based on a custom PCB for the beacon mounting on the robot and a wearing tag by the human. The preliminary test is performed in a real scenario in particular, near a reproduction of the LHC tunnel. A PI velocity controller based on the UWB localization system for the CERNBot is implemented in order to keep fixed the human-robot distance when the human is moving. The distance and the radiation level are shown on the Sony SmartEyglasses.

6. Tutorship

I didn't a tutorship activity.