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FINS: Model-Based Design of Flying Indoor Navigation System

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Abstract— In this paper, we introduce a simple and accurate indoor navigation system that can track and re-direct flying objects modeled from digital pixel designs. Using Pseudolite idea, this system works accurately indoors in spite of a high noise and multipath, to track and control helicopters with mounted LED lights mimicking the digital designs. The system was built using Simulink and Universal Software Radio Peripheral (USRP) hardware. It can also be used for many indoor applications, for example, tracking persons or things in a hospital with high accuracy.

I. INTRODUCTION

Model-Based Design (MBD) is the way to move design tasks from the lab and field to the desktop. It defines the problem and solution using a mathematical analysis and visualization processing. It is used in many applications such as motion control, industrial equipment, aerospace, and automotive. In our paper we use MBD method to address the indoor navigation problem for flying object in indoor environment using GPS receiver. Finding the location of object in indoor environment faces a lot of problems of multipath and noise. They make tracking of object is very difficult especially if the applications need high accuracy tracking. Our application is called Flyfire. It is a project initiated by the SENSEable City Laboratory in collaboration with ARES Lab (Aerospace Robotics and Embedded Systems Laboratory) aims to transform any ordinary space into a highly immersive and interactive display environment. The Flyfire project sets out to explore the capabilities of this display system by using a large number of self-organizing micro helicopters. Each helicopter contains small LEDs and acts as a smart pixel. Through precisely controlled movements, the helicopters perform elaborate and synchronized motions and form an elastic display surface for any desired scenario. With the self-stabilizing and precise controlling technology from the ARES Lab, the motion of the pixels is adaptable in real time. The Flyfire canvas can transform itself from one shape to another or morph a two-dimensional photographic image into an articulated shape. The pixels are physically engaged in transitioning images from one state to another, which allows the Flyfire canvas to demonstrate a spatially animated viewing experience. Our system depends on using Pseudolites architecture in indoor environment to generate GPS signal that is difficult to receive in this case. The flying object collects the GPS signal generated from four Pseudolites located one in each corner of our lab room. We use Simulink from Mathwork to generate the navigation framework and processing program to test and visualize the results. Navigation framework includes two parts. The first part is a set of indoor location algorithms. It includes the simulation of GPS signals (C/A code signal, carrier signal) [1] for four Pseudolites, the GPS receiver of the flying object, and an algorithm to calculate the position using these signals. We use Universal Software Radio Peripheral (USRP) [2] to transmit and receive the GPS signal. Also, it is used to control and synchronize between Flyfires.

Ettus Research is the world's leading supplier of low-cost software defined radio platforms, including the popular Universal Software Radio Peripheral (USRP) family of products [2]. With a low overall system price, expansive capabilities and software availability, the USRP is used by thousands of engineers worldwide and remains the top choice in software defined radio (SDR) hardware for algorithm development, exploration and prototyping.

The USRP family of products is designed for RF applications from DC to 6GHz. The USRP N200 and N210 as shown in Figure 1 provide high-bandwidth, high-dynamic range processing capability. The USRP N210 is intended for demanding communications applications requiring this type of rapid development. The product architecture as shown in Figure 4 includes a Xilinx Spartan 3A-DSP 3400 FPGA, 100 MSPS dual ADC, 400 MSPS dual DAC and Gigabit Ethernet connectivity to stream data to and from host processors.

For flying object we try to make simple simulation for controlling, communicating and processing the flying objects. It also includes the location calculation corresponding to other flying objects to avoid interaction and gives required shape. For the testing and design verification we use processing program to visualize the results (required and simulated paths) at each unit of time and calculate the percentage of error in the location.

From our results we see that MBD gives a lot of advantages in saving time and increasing accuracy for development such
complex system. Also it gives opportunity to reuse and expand the design for other applications.

II. MODEL BASED DESIGN OF INDOOR LOCATION AND FLYFIRE SYSTEM

Figure 2 shows the flow diagram of flyfire system design. We use Simulink to design and implement indoor GPS location, helicopter model and control system. GPS system includes the design of GPS transmitter and receiver. We use four Pseudolites [3] located in corners of our lab room. Figure 3 shows the distribution of Pseudolites in Senseable city lab, MIT, room 9-215.

The designer will give the required picture, which will display in digital by using flyfire, to Matlab with dimensions and the movement’s pattern. First we will run the GPS system to figure out the position, and synchronous between the Pseudolites. Control system will send and receive commands from and to flyfire to see the errors in position and give the correction to flyfire.

For flyfire part, we model the helicopter using Simulink and we use small chip inside the helicopter. As shown in Figure 2 the area of board is 6 cm$^2$ board with weighs 1.6 grams ,single 3.7V lithium polymer cell, GPS receiver, 3-axis accelerometer (sensitive) and 3-axis accelerometer (large range). The complete GPS system is implemented using Simulink and USRP devices as transmitter and receiver as shown in Figure 4. PC is connected to USRP through Gigabit Ethernet connector. We use WBX 50-2200 MHz Rx/Tx daughterboard and LP0965 Antenna. It works in range from 850 MHz to 6.5 GHz Log Periodic PCB directional antenna, at 5-6dBi Gain. It is used with any daughterboard that operates within 850 MHz to 6.5 GHz frequency range. It connects to USRP using SMA connector.

We use smartphone to track the Flyfire. We implemented the application in smartphone using processing program [4]. The tracking position is given in 3D and we can see the position of four pseudolites in the same application.

We run the program using two Pseudolites (TX and RX) as shown in Figure 4 with distance is 28cm. The measured distance is 26.91cm. In this case the system will have less traffic, less energy consumption and increase contention win of sending messages.

III. CONCLUSION

The requirement of accurate indoor location is increased year after year especially of very bad resolution of GPS in indoor environment. There are many methods were used in indoor localization for example WiFi and UWB but they are still not accurate and very expensive.

In this paper we introduce high accuracy indoor location using GPS and Pseudolite idea. We apply indoor location in Flyfire project where high accuracy indoor localization is required. We use Simulink and USRP to implement indoor location, flyfire control and communication systems.

Using MBD in implementing the system makes the design simple, accurate, easy to test and reuse for other indoor applications.

REFERENCES