Automation of the Maritime UAV Command, Control, Navigation Operations, Simulated in Real-Time Using Kinect Sensor: A Feasibility Study

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Abstract**—**This paper describes the process used in the automation of the Maritime UAV commands using the Kinect sensor. The AR Drone is a Quadrocopter manufactured by Parrot [1] to be controlled using the Apple operating systems such as iPhones and Ipads. However, this project uses the Microsoft Kinect SDK and Microsoft Visual Studio C# (C sharp) software, which are compatible with Windows Operating System for the automation of the navigation and control of the AR drone.

The navigation and control software for the Quadrocopter runs on a windows 7 computer. The project is divided into two sections; the Quadrocopter control system and the Kinect sensor control system. The Kinect sensor is connected to the computer using a USB cable from which commands can be sent to and from the Kinect sensors. The AR drone has Wi-Fi capabilities from which it can be connected to the computer to enable transfer of commands to and from the Quadrocopter.

The project was implemented in C#, a programming language that is commonly used in the automation systems. The language was chosen because there are more libraries already established in C# for both the AR drone and the Kinect sensor.

The study will contribute toward research in automation of systems using the Quadrocopter and the Kinect sensor for navigation involving a human operator in the loop. The prototype created has numerous applications among which include the inspection of vessels such as ship, airplanes and areas that are not accessible by human operators.

Keywords**—**UAV, AR drone, Kinect Sensors, Automation, Real time, C sharp, Microsoft Kinect SDK.

I. Introduction

UNMANNED Aerial Vehicles, (UAV), are important in the Aerospace research industry because of their potential applications. The unmanned vehicles are becoming increasingly popular because of their ability to fly into areas that are not accessible by human operators (Mariusz Wzorek, 2006). These aerial vehicles are cheap and readily available depending on their application. Often times, researchers continue to build upon the vehicles adding on additional payload to carry out the desired tasks at hand. There are several types of UAV however this paper will concentrate on the Quadrocopter. Quadrocopters are VTOL, Vertical Takeoff and Landing. This kind of vehicle is useful in areas where there is limited take off area such as on top of buildings or on a ship.

In the area of Mechatronics and Aerospace engineering Robotics and automation is a continuous research area which involves implementing system that imitate the way humans perceive information. Most research has been carried out in the areas involving the use of autonomous vehicles to investigate stereo vision sensors and how they are used to imitate human vision. Kumano et al (2000) researched the various methods that could be used in transmitting real time data as perceived by the autonomous mobile robot. The data transmitted is then used by the robot to avoid any obstacles in its mapped path. However, the Kinect depth sensors are used in the automation of the system translating the gestures into maneuvers.

This project uses a "parrot AR. Drone", a quadrocopter that was created as a gaming platform for aviation lovers of all ages. This platform slowly became integrated in the research study environment and as such is being modified by developers, contributing in the area of aerospace enormously (Adam Salamon, 2008)[2]. In this project the quadrocopter is being used as a research tool to aid research.

The project consists of a communication network made up of a quadrocopter, "parrot AR. Drone", "Kinect sensor" and a laptop. The aim of the project is to automate the procedures for navigation and control of the quadrocopter using the "Kinect sensor". The prototype could be used in various areas and departments. The project has been designed to support operators to identify or mark out objects in remote locations. This is made possible by the camera system onboard of the drone which can be navigated and controlled remotely by the operator. The data obtained could then be used for further research. The prototype would be used to inspect vessels such as ships, airplanes, or areas that are affected by bush fires and report back the findings in real time. The data transmitted would enable the ground operators to access the situation on the ground, enabling appropriate actions and tactics to be applied to the situation at hand.

In recent studies, the Kinect sensors have been used for robotic vision and control because the sensors can be utilized to transmit and integrate the human movements and actions in the control loop of the autonomous vehicles in real time. The Microsoft Kinect 360 sensors have two monochrome CCD cameras equipped with 90 degree wide-angle lenses [7]. John

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Stowers, et al [5] used the depth map from the Microsoft Kinect sensor as a controller, in combination with the Hough transform to calculate with high precision the depth of the environment. The Hough Transform is used when identifying complex objects within data. This technique enabled the designers and the quadrocopter calculate the distance between the ground and the autonomous vehicle.

Similarly the research project involves the use of the Kinect depth camera to hand track the gestures and movements of the operator's hand. The gestures are then interpreted into specific commands sent to the computer henceforth controlling the quadrocopter.

This paper presents the methods and techniques used in the implementation of the Kinect sensor-quadrocopter automation system. The system is implemented entirely in C#, a programming language. The developers of the Microsoft Kinect sensor and the Parrot AR drone have provided required libraries in C# to aid with further development of the devices. The arrangement of the system is represented in Fig. 1.

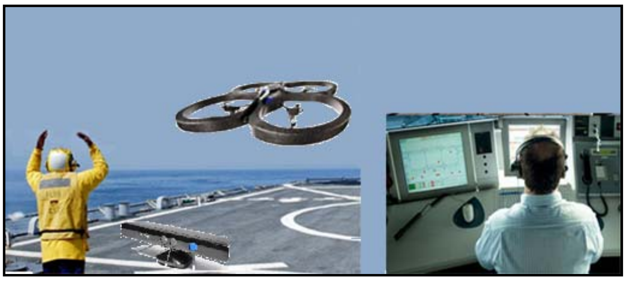


Fig. 1 The Illustration of Intelligent M-UAV Air Operation Scenario on Ship Deck

The different parts of the system make up the various subsystems which have separate control systems and ways of communication. After the broken down implementation, the complete system is then compiled together resulting into a complete automated system. This paper describes the implementation procedure of the subsystems and what it is comprised.

II. Methodology

A. Subsystems

i. Parrot AR. Drone

The Parrot AR. Drone was released by the Parrot Company in 2010 with the aim of integrating a micro UAV in the Video games market as part of home entertainment. The AR. Drone was designed to be operated using Apple gadgets such as the iPhone, iPad or iTouch, user-friendly interfaces. These interfaces are readily available. The project AR. Drone involved the use of embedded systems algorithms for stability implementation. [11]. The technology has since been introduced to the research industry in academia as well as Military, Defense.

The AR. Drone is a quadrocopter that receives navigation wirelessly from the controlling interface. It is comprised of motion sensors, an Ultrasound telemeter, Inertia measurements, a bottom facing camera, and an inertia measurement unit (IMU). The IMU is 6DOF based and is used to the attitude measurements of the yaw, pitch and roll used in the navigation of the quadrocopter and aided tilt control.

The Ultrasound telemeter measures the vertical speed and the *automatic altitude stabilization* for the altitude control which are used in the estimation of the drone's altitude. All the motion sensors on the AR. Drone are located at the bottom of the Hull [1].[4] &[8].

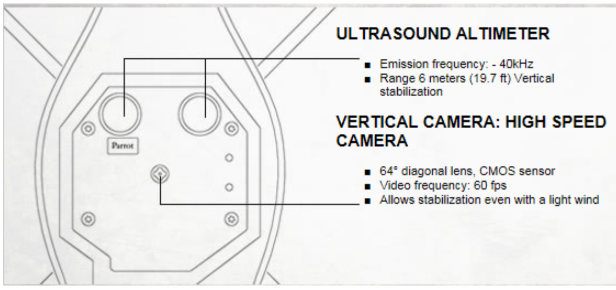


Fig. 2 Parrot AR. Drone bottom sensors [1]

Bristeau et al, in their paper present the navigation and control system within the AR. Drone. The diagram in Fig. 3 shows how the various parts and sections of the AR. Drone interact with each other outputting a variety of states and attitudes desired by the pilot.

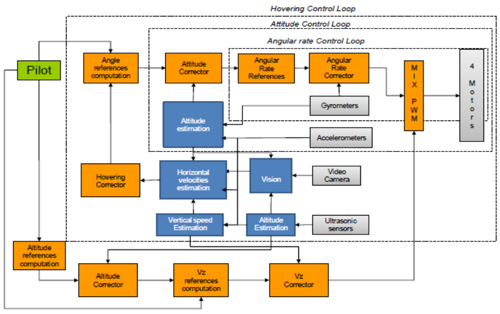


Fig. 3 Data transfer within the AR Drone [11]

As presented in Fig. 3, shows the communication links between the various components within the AR. Drone resulting into the various states or attitudes desired by the pilot. However, this project does not go into the depth of the various components but instead how the commands are sent to and from the AR. Drone to achieve the desired maneuver. The method and commands sent to the AR. Drone to execute different states are discussed in detail within the system control section of the paper.

ii. Microsoft Kinect Sensor

The Kinect sensor is a motion-sensing device that is comprised of three sensors: an IR laser projector, a color camera, and an IR camera.

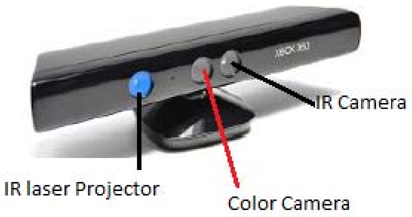


Fig. 4 Microsoft Kinect Sensor

The Kinect sensor uses the different sensors to recognize and track the human body. The data tracked is used for the game console. The Kinect sensor together with the Kinect 360 console was designed for game environment. However, this paper describes how the data extracted from the Kinect sensor is used in the automation and the control of the UAV, AR. Drone incorporating real time pilot control of the quadrocopter.

The *Infrared (IR) Camera* known as the RGB camera detects the **R**ed, **G**reen and **B**lue color components of an image it captures. The color VGA video camera assists in the recognition on facial features and other features by detecting the three colors. The *Infrared (IR)* laser Projector, is a depth sensor which works together with a monochrome CMOS (complimentary metal-oxide semiconductor). It projects its surroundings in 3-D regardless of the lighting. [3]. The Kinect also contains *Multi-array microphones* that isolate the players' voice from that of the background. It is essential for the player to be stationed a few feet from the Kinect sensor, allowing the Kinect to work efficiently. The sensor's depth and video cameras have a 640 x 480 pixel resolutions that are run at 30 frames per second. This feature allows the videos and data transmitted by the Kinect to be transmitted in real time [3].

III. Automation and Control

Proposed system:

This section discusses the entire system and how the separate subsystems communicate with each other and the type of data transferred to and from each subsystem.

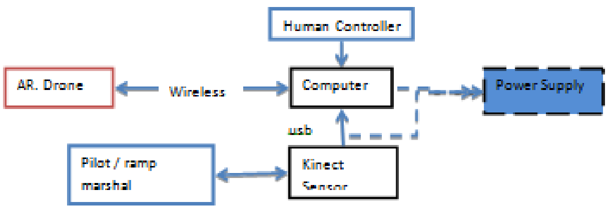


Fig. 5 The PROPOSED system

Fig. 5, shows the entire system implemented and how each sub block communicates with the other. The AR. Done Wi-Fi capabilities enable it to connect to the computer with wireless capabilities. The AR. Drone is powered by a LiPo battery with a flight time competence of 12- when flying at a speed of 5 meters/second (16.4 feet per second) [4].

The Kinect sensor is connected to the computer via a USB cable. The Kinect sensor needs to be powered to a power source. The availability of the Kinect sensor and AR. Drone libraries allows the transfer of data to and from the computer. The data from the Kinect sensor in the form of gestures is transferred to the AR. Drone wirelessly to enable the control of the quadrocopter.

The computer acts as the interface between the quadrocopter and the Kinect sensor. An automation program implemented in C# runs on the computer and when started, connects to both the quadrocopter and the sensor as shown in the flow diagram in Fig. 6, below.

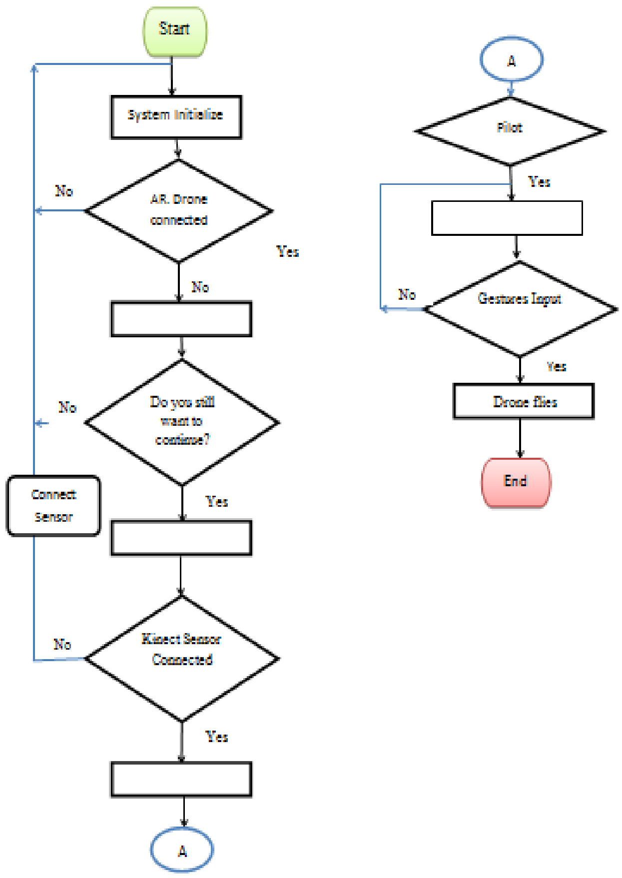


Fig. 6 The System State Diagram

The flow chart shows the steps and the data flow within the program used to automate the control of the AR. Drone with the aid of the Kinect sensor with a human in the loop.

Automation procedure

The automation procedure uses the depth image data of the Kinect sensor and converts it to skeletal data. From skeletal data, joint information is extracted and used for various gestures. Each joint is allocated within the space, x, y and z coordinates making it accessible for use and data allocation. The coordinate on which the skeletal data is based is a representation of the 3-D full skeleton;

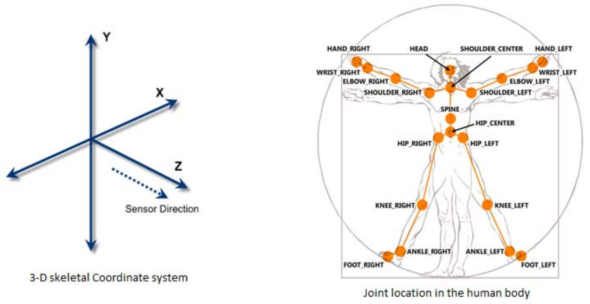


Fig. 7 Kinect Sensor Skeletal data coordinate system and Joint data [10]

IV. Gestures

Using the skeletal and joints' data obtained from the Kinect, the gestures described below are used as signals that are sent to the AR. Drone to control and maneuver the quadrocopter.

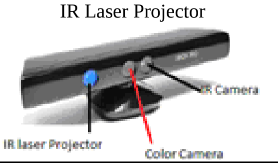
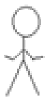
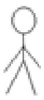
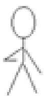
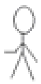
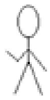
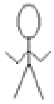
The gestures are captured by the depth sensors by taking the coordinates of the joints that are used. The x, y and z coordinates of the joints are used to control the AR. Drone. However the AR. Drone states are calculated between -1 and 1 and the values are then sent to the Drone using the UDP single packets. The values between -1 and 1 represent the speed of the Drone of its configured power [11].

For example:

A command to be sent to the AR. Drone for the float 0.1 of the configured power of the drone would be sent in the form of a 32-bit integer. However the conversion would be carried out as follows; [1] & [4].

(Float) 0.1-> (hexadecimal) 3DCCCCCD-> (32-bit integer) 1036831949

TABLE I
Operator Gestures Captured By Sensors

Command	Human Gesture	Sensor Gesture using IR Laser Projector
		 IR Camera; IR laser Projector; Color Camera
Takeoff		
Land		
Right		
Left		
Forward		
Backward		

Example Algorithm in C#

```
If ((leftHand Y > leftElbowY  and rightHand Y > rightElbow Y ))
 {
   Return String.Format ("AT*PCMD= %d, 1, 0, 1065353216, 0, 0", sequenceNumber)
     // Quadrocopter (Drone moves backwards
  }
 Else if ((leftHand Y > leftElbow Y  and rightHand Y > rightElbow Y ))
    {
Return String.Format ("AT*REF= {0}, {1}\r", sequenceNumber, 290718208);
// Quadrocopter (Drone Takeoff

    }

 Else if (rightHand X > rightElbow X)
  {
   Return String.Format ("AT*PCMD= %d, 1, 1065353216, 0, 0, 0", sequenceNumber); //roll right

   // Quadrocopter (Drone turns right
    }
 Else if (rightHand X<rightElbow X && leftHand X < leftElbow X)
    {
      return String.Format("AT*PCMD= {0},{1},{3},{4},{5}\r", sequenceNumber,1, -1082130432,0,0,0);

      // Quadrocopter (Drone) turns Left
}
```

The sample code provided shows a sample of different commands that have been sent from the Kinect to the Drone and the actions that are executed.

V. Results

Fig. 8 Takeoff and Left control results

VI. Conclusion

The paper describes the methodology used to automate the control and navigation system of the AR. Drone with the use of the Kinect depth sensor. The automation procedure transfers data from the pilot in real time. The data in gesture form is translated into quadrocopter maneuvers. The intelligent system has been tested indoors. It also went through a number of real time outdoor trials and, due to the usefulness of the system, is going through a number of improvements as a future development plan.

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References

[1] (2012). Parrot AR. Drone, flying Video Game, Developer SDK 1.5. Parrot Company.
[2] Adam Salamon, D. H. (2008). Increasing Situational Awareness Through The Use Of Uxv Teams While Reducing Operator Workload. Lockheed Martin.
[3] Crawford, S. (2012, October 1). How Microsoft Kinect Works. Retrieved 10 1, 2012, from How stuf fworks: http://electronics.howstuffworks.com/microsoft-kinect2.htm
[4] Drone, P. A. (2012). www.Parrot.com. Retrieved 10 2, 2012, from A Technological first : http://ardrone.parrot.com/parrot-ar-drone/en/technologies
[5] John Stowers, M. H.-S. (2011). Quadrotor Helicopter Flight Control Using Hough Transform and Depth Map from a Microsoft Kinect Sensor. Conference on Machine Vision Applications, Nara, JAPAN, 5.
[6] Mariusz Wzorek, D. L. (2006). GSM Technology as a Communication Media for an Autonomous Unmanned Aerial Vehicle. 21th Bristol UAV Systems Conference, (p. 15). Link¨oping, Sweden.
[7] Masako Kumano, A. O. (2000). Obstacle Avoidance of Autonomous Mobile Robot using Stereo Vision Sensor. 6.
[8] Parrot. (2012). Parrot AR. Drone Overview.
[9] Pierre-Jean Bristeau, F. C. (2011). The Navigation and Control technology inside the AR.Drone micro UAV. 18th IFAC World Congress, (p. 8). Milano, Italy.
[10] Robotics, M. (2012). Kinect Sensor. Retrieved 10 1, 2012, from Microsoft: http://msdn.microsoft.com/en-us/library/hh438998.aspx
[11] Sandler, A. A. (2012). How to Control AR.Drone Movements During Flight. Retrieved 10 1, 2012, from Robot -App Developers: http://www.robotappstore.com/Knowledge-Base/How-to-Make-ARDrone-Take-Off-or-Land/97.html
[12] Totilo, S. (2010, 11 4). Review: Kinect. Retrieved 10 11, 2012, from kotaku: http://kotaku.com/5680501/review-kinect
[13] Walter Hickey, R. J. (2012, 08 17). These Ships Have Russia Considering A Missile Strike Against Europe. Retrieved 10 11, 2012, from Business Inside, Military and Defence: http://www.businessinsider.com/meet-the-destroyers-that-are-the-lynchpin-of-the-european-missile-shield-2012-8?op=1