Design and Development of A Smart Parachute Control System for Military and Civilian Applications

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ABSTRACT
The parachute is a folding, umbrella like fabric device which is mainly employed to slow down the fast moving objects or people in airspace. Parachutes have employed in adventure sports, military and cargo drop etc. Sometimes even after deployment these devices fail to provide safety to the diver like in case of blackout. Even the drop one of a conventional unmanned parachute cannot be manipulated much. In literature advancement in parachute technology has taken place mostly mechanically. Hence there remains a scope of development in the field of its avionics. In this paper, a model is proposed not only to deploys the parachute at a safe height but also navigates the parachute to a safe landing zone, avoiding water and trees etc. The limitations of the present model are using Global Positioning System (GPS) to guide the system. In future more robust sensors can be used and data from multiple sensors to increase the accuracy.
Keywords: Parachute, Flight Control System, GPS, Compass

I. INTRODUCTION:

The parachute is a simple piece of technology with one simple purpose, to deceleration fast moving objects. The wide, flat expanse of fabric catches the air and pulls back on the object or subject to which it's attached. These devices are used in a number of different settings, ranging from military to recreational applications. Automatic activation device (AAD) in skydiving refers to an electronic-pyrotechnic or mechanical device that automatically opens the main parachute container at a preset altitude or after a preset time. The AADs are typically used to open the reserve parachute container at a preset altitude if the descent rate exceeds a preset activation speed. This indicates that the user has not opened his or her parachute, or that the parachute is malfunctioning and is not slowing the descent rate sufficiently. The older style mechanical AADs are falling out of fashion in favor of the newer style electronic-pyrotechnic models. The built-in computers in the newer models can make much better estimates of the altitude and the vertical speed, therefore making the units more reliable than the older types.

Moreover with the current system is not possible for the pilot to know his/her own location which is why even after landing the wing commander was unaware of his own current location. This incidence motivated us to design a parachute which can help the pilot to get back to safety without the need of any manual control.

On 27 February 2019, Varthaman was flying a MiG-21 as a part of a sortie that was scrambled to intercept an intrusion by Pakistan aircraft into Jammu and Kashmir. In the dogfight that ensued, he crossed into Pakistan territory where he was struck by a missile. Varthaman ejected and descended safely in the village of Horran in Pakistan administered Kashmir, approximately 7 km from the Line of Control. This incident motivated us to do this research work.

Our objective is to design and develop an automatic parachute control system with self-navigation and autopilot capabilities and embed this system in the para-jumpers backpack. This system gets the current position of the subject with global reference accurately and finds the nearest safest landing zone using the algorithm which we developed and pilot itself to that position against external interfaces without any input from the diver. This system can also be used for dropping payload with unmanned parachutes which has applications like safe landing of crew module etc. The remaining paper is organized as follows. The Section II describes the basics of parachute technology. Section III provides detail information about parachute and the electronics components required for device. The overview of proposed model latest advancements parachute technology and also the need of an autonomous system in Section IV. Section V presents the proposed model and the algorithms required for the navigation of the parachute. In Section VI, proposed hardware set-up has been presented and the paper is concluded in Section VII.

II. BASICS OF PARACHUTE TECHNOLOGY:

In this section, we have discussed the basics of parachute technology. In literature, we find research work related to the mechanics of the parachute including the type fabric and shape of the canopy etc, but very few works can be found on the electronics and Automation of a parachute. The fluid dynamics of parachute Inflation presented by C. Peterson [1] explains the mechanics behind parachute in a great depth. Daniel Preston [2] presents a design of an autonomously guided parachute system for cargo drops that divides the requirements of guidance and soft landing into separate parachutes. Said invention includes a high wing-loaded ram air parachute for guidance, a larger round parachute for soft landing, a harness/container system, flight computer, position sensors and actuation system. The system is dropped from an airplane. A predetermined period of drogue fall ensures a stable position prior to deploying the guidance parachute. The flight controller determines a heading to intersect with an area substantially above the desired target and controls the guidance parachute via pneumatic actuators connected to the parachutes steering lines to fly on that heading [10].

Willard D Carpenter devised a velocity/altitude sensing automatic parachute release System [3] similar to Automatic Activation Device which saves life in case the diver is not able to open the parachute on time. Joint Precision Airdrop System (JPADS) which is an American military airdrop system which uses the Global Positioning System (GPS), steerable parachutes, and an onboard computer to steer loads to a designated point of impact (PI) on a drop zone (DZ) [4-7]. It integrates the U.S. Army's Precision and Extended Glide Airdrop System (PEGASYS) and the U.S. Air Force's Precision Airdrop System (PADS) program. Low Cost Parachute Guidance, Navigation, and Control is a similar work presented by Henry D. Scott [8-9].

All of these systems are only meant for cargo drop and are targeted to land at a pre defined position but Automatic parachute control system dynamically chooses the most favourable landing zone and drives parachute to that particular zone, which is the edge of our system over others.

In this section we discuss some of the basic terminologies related to parachute which is be used in the latter part of this thesis. We discuss the different types parachutes used and which one is suitable for our work. We also discuss about different sensors which can be used to provide feedback to the parachute about the present location, altitude speed heading etc. of the parachute.

Steering Lines: Steering Lines are strings attached to the control surfaces of a parachute and are used to control it.

Toggles: The toggles are yellow handles attached to the end of steering lines. Steering toggles allow askydiver to easily maneuver the canopy both directionally and for soft landings fly 'flaring'.

Canopy: A canopy is a parachute. In the civilian world of skydiving, a parachute is often referred to as a canopy.

Heading: The term heading is used a lot in skydiving and gives reference to a direction. Often times you'll hear jumpers talk about an on or off heading during a parachute's deployment or exiting on heading.

II.A. Types of Parachutes

3.3.1. Round type Parachute: It is used in the military and as emergency parachutes; these simply rely on drag to slow a descent, rather than having any lift. Made from dome-shaped canopies, they are often referred to as 'jellyfish chutes' and are seldom if ever used by modern jumpers. Fig. 1 shows a Round Type Parachute.

Figure 1: A Round Type Parachute

3.3.2. Cruciform Parachute

It is designed to provide a steadier descent by reducing oscillation, these square-shaped chutes have been modified in recent times by the US Army called the ATPS system and can reduce descent speed by as much as 30. This also reduces the chance of landing injury. However, again, these chutes are rarely used outside military man oeuvres. Fig. 2 shows a Cruciform Parachute.

Figure 2: Cruciform Parachute

Figure 3: Annular Parachute

3.3.3. Annular Parachute

It is a ring or series of concentric ring shaped parachute that pulls the apex close to the load. They have a lower drag factor than conventional round parachutes. The rear position of the vents can give the jumper considerable forward speed in descent. Most modern parachute types are ram-air, specifically in sports jumping. The self-inflating airfoils, known as parafoils, give the jumper greater control of speed and direction and will spread the stress of deployment (a major problem on some older chutes). Two layers of fabric allow air to penetrate from vents in the front and form cells. Fig. 3 shows an Annular Parachute.

3.3.4. Ram Air Parachute

This type parachute provides the best maneuverability therefore in our case. This type of parachute is best suited and has a glide ratio of 1:3 which means for a drop of 1ft it travel 3ft forward. These parachutes can be controlled using its control lines. Due to its high velocity this parachute is not generally used by pilots while ejection as the traumatized pilot is unable to control its velocity. But making this parachute fully autonomous can solve this issue. Fig. 4 shows a Ram Air Parachute

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Figure 4: Ram Air Parachute

II.B. Applications of parachute:

i. Skydiving: Skydiving is jumping out of an airplane for the fun of it and releasing a parachute long before you hit the ground. This gives an exciting feeling of free fall for a few seconds. However, this is not the only use of a parachute for recreation: parasailing is another example, which involves a participant with a parachute being pulled behind a boat.

ii. Military: In addition to dropping soldiers on a battlefield without needing a landing strip for the airplane, parachutes also are used by the modern military to drop supplies and equipment. Instead of a single parachute that is large enough to accommodate a person, these larger drops call for several parachutes large enough to drop the equipment safely.

iii. Airplanes and Drag Racing: Vehicles used in drag racing travel extremely fast for a short period of time, but it takes space and time to slow down. That's where this specialized parachute, sometimes called a ”drogue chute,” comes in. These small parachutes help decrease the length of track needed to slow down. Instead of being used vertically, these parachutes are employed horizontally.

II.C. Limitations of a Conventional Parachute System:

Technological advancements in the field of aviation had made flight safer than ever before, but with increasing number of aircraft in flying, mishaps do occur on a regular basis. In a situation of critical emergency not much can be done in a civilian aircraft but in a military aircraft the pilots can eject from the cockpit and use parachutes to land safely by reduce their terminal velocity. After the ejection Parachutes are the only dependable safety device for landing but due to trauma it is difficult for the pilot to control its landing. Sometimes hard landings, landing in the bushes, water and enemy territory occur which life is threatening.

Apart from Advance Activation Device (AAD), not much automation has taken place in the parachute technology. Not just in military but in civilian applications also parachutes malfunctions happen. A parachute malfunction is probably the scariest thing that can happen in a skydiver's day, but thankfully, he has a backup parachute that can be deployed. Even so, it's no guarantee of success. Inexperienced sky divers often face lethal situation due to partial malfunction of parachute and drop zone problems.

III. COMPONENTS OF PARACHUTE TECHNOLOGY

In this Section, different components of parachute technology are described here. Figure 5 represent the whole block diagram of the parachute system.

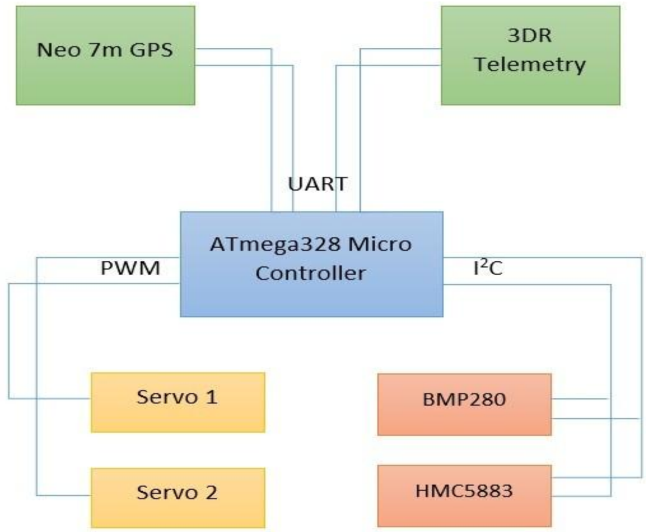

Figure 5: Block Diagram of the Parachute System

The different components are briefly described in the following.

i. Sensors:

In a multi dimensional autopilot system there are many constraints to be considered. data like altitude, heading, latitude, longitude (current position and destination position),velocity acceleration etc. is required by the computation unit to control the parachute's path. This data is fetched using different sensors.

ii. Neo 7m GPS Module:

It is a GPS navigation GPS receiver module piece of hardware that you add to other piece of hardware (e.g. car head unit, Raspberry PI, Arduino even computer) to give it the possibility to receive information from GPS satellites. NEO-7M-C onboard, with high-gain active antenna and IPX interface, for connecting different active antennas have used in parachute technology. Chargeable backup battery, keeps the ephemeris data when power down, supports hot starts

iii. HMC5883L Triple Axis Magnetometer:

This is a breakout board for Honeywell's HMC5883L, a 3-axis magnetometer. Magnetometers have a wide range of uses. The most common include using the chip as a digital compass to sense direction or using them to detect ferrous (magnetic) metals. When current flows through a wire, a magnetic field is created. This is the basic principle behind electromagnets. This is also the principle used to measure magnetic fields with a magnetometer. The direction of Earth's magnetic fields affects the flow of electrons in the sensor, and those changes in current can be measured and calculated to derive a compass heading or other useful information.

iv. BMP280 barometric pressure sensor module:

BMP280 is an absolute barometric pressure sensor especially designed for mobile applications. The sensor module is housed in an extremely compact package. Its small dimensions and its low power consumption allow for the implementation in battery powered devices such as mobile phones, GPS modules or watches. As its predecessor BMP180, BMP280 is based on Bosch's proven Piezo-resistive pressure sensor technology featuring high accuracy and linearity as well as long term stability and high EMC robustness. Numerous device operation options offer highest flexibility to optimize the device regarding power consumption, resolution and filter performance. A tested set of default settings for example use case is provided to the developer in order to make design-in as easy as possible.

v. ATmega328 Micro Controller:

The ATmega328 is a single-chip microcontroller created by Atmel in the megaAVR family. It has a modified

Harvard architecture 8-bit RISC processor core. The Atmel 8-bit AVR RISC-based microcontroller combines 32kB ISP flash memory with read-while-write capabilities, 1kB EEPROM, 2kB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five softwareselectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves throughput approaching 1 MIPS per MHz

vi. 3DR radio telemetry kit:

The 3DR Radio Telemetry of 3D Robotics is an ideal module to set the remote sensing connection module between APM and ground station. It features small volume, cost effective, wider transmission range, and it allows us to do things that other data transmission modules can't do. These modules use the UART communication protocol to communicate with the micro controller and uses radio communication at 433MHz to communicate amongst the pair of transceivers to wireless communicate data to the base station. This module is used by us to monitor data wirelessly.

IV. OVERVIEW OF PROPOSED MODEL

In this Section, we present our proposed idea of an automatic parachute control system in detail. In case of emergency, after ejection our objective is to guide the parachute from initial position *A* to a safe landing zone *B*. To accomplish this task we must smartly choose the nearest place which is safe for the pilot. Figure 6 represents the flowchart of our proposed Parachute System.

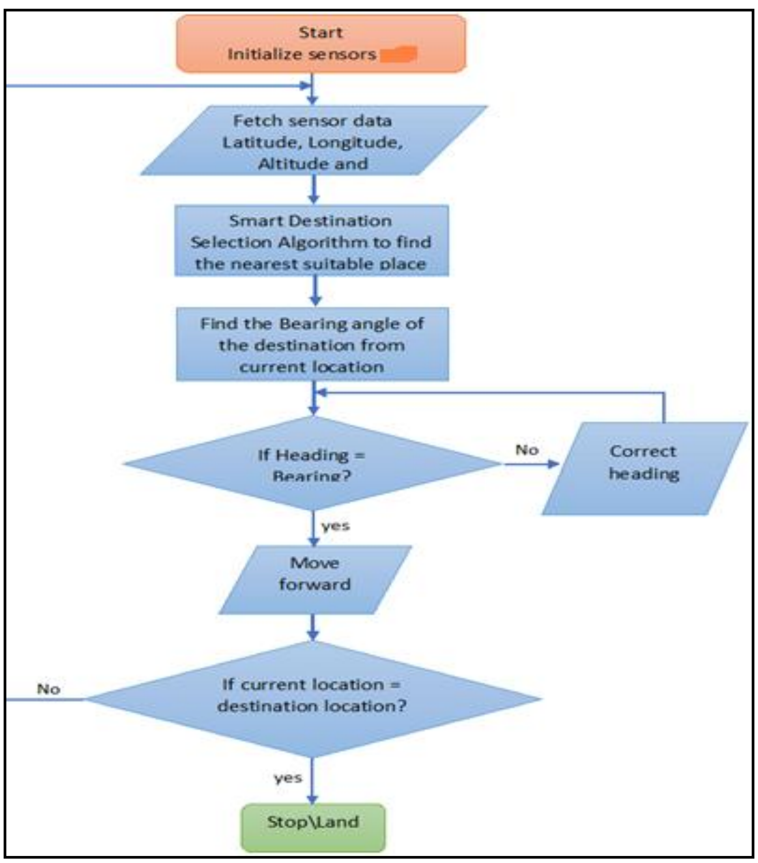

Figure 6: Flow chart of the system model

We have devised two navigation algorithms and named them as a) **smart destination selection algorithm** and b) **parachute pilot algorithm**; the first one finds the most suitable landing position and the latter drives the parachute in the planned path. Two proposed algorithms are explained briefly.

a) Smart Destination Selection Algorithm

This Algorithm returns the coordinates of the closest safe landing zone which is used by the system to plan its path. This algorithm inputs two parameters one is an array of coordinates from the map this is static data, second one is the current location of the parachute which is dynamic in nature. This algorithm is called multiple times throughout the journey so the destination also keeps changing accordingly. This algorithm minimizes computing by reducing the number of coordinates to be compared and uses less iteration to accomplish the task. This is done by Interpolation of the required coordinate from few predefined map coordinates called tower coordinates.

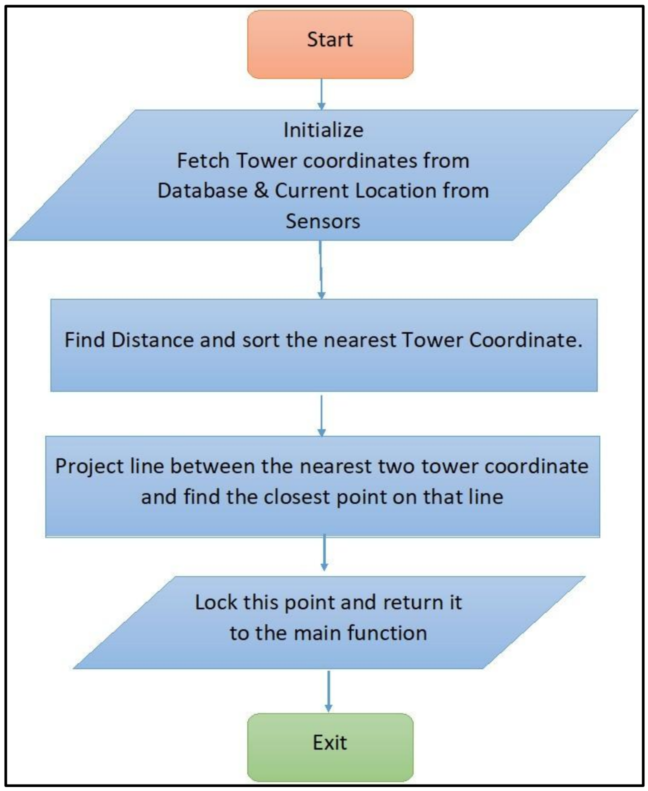

Figure 7: Flow chart of Smart Destination Algorithm

b) Parachute Driving Algorithm:

This algorithm drives the actuators using the input from the compass sensor and bearing angle. The main task of this algorithm is to correct the heading of the system so that the correct path can be followed.

V. HARDWARE SETUP:

In this Section, actual hardware implementation of our proposed work is described here. To drive the autopilot system we used Atmel ATmega328P micro controller as the main processing unit on Arduino single-board micro controller with ample number of GPIOs it was pretty convenient for us to interface with various sensors and Actuators. Pin configuration of various sensors with the micro controller is shown in Table 1.

Table 1: Pin configuration of various sensors with the micro controller

Sensors/Actuators	Pin	Arduino Pin
Neo 7M GPS Module	Rx	D2 Soft Tx
	Tx	D3 Soft Rx
	Vcc	Vcc
	GND	GND
Bmp 280 pressure sensor	SDA	A4 SCL
	SCL	SCL A5
	Vcc	Vcc
	GND	GND
Honeywell HMC5883L	SDA	A4 SCL
	SCL	A5 SCL
	Vcc	Vcc
	GND	GND
3DR Radio Telemetry Module	Rx	D6 Soft Tx
	Tx	D7 Soft Rx
	Vcc	Vcc
	GND	GND
Servo 1	PWM Signal	D4
	Vcc	Vcc
	GND	GND
Servo 2	PWM Signal	D5
	Vcc	Vcc
	GND	GND

The Figure 8 shows the final hardware of our proposed work. This working model is successfully able to run.

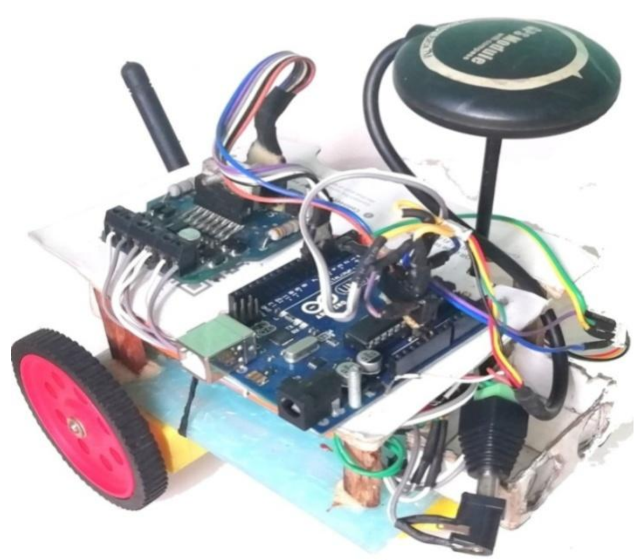

Figure 8: Prototype of ground robot for testing the algorithm

VI. COST ESTIMATION

The different components of proposed design are listed and their corresponding price is also estimated in this Section. The estimated cost of the hardware used is shown in Table 2.

Table 2: Cost Estimation (in INR Rupee)

Item	Cost (Rs.)
Neo 7m GPS Module	1050
BMP280 Barometric pressure sensor	185
HMC8853L Magnetometer module	365
ATmega328 BOard	500
3DR Telemetry Module	1500
9G Servo	200
Miscellaneous	300
Total	**4100**

The estimation is for hobby grade sensors military grade hardware will be more expensive and can cost upto 15000 rupees. Proposed cost is lower than other existing devices. The position sensing Sensor used is Neo 7m GPS module which is effective but is also prone to disturbances at times. It is also not so accurate in estimating the height accurately for which we use barometric pressure sensor.

VII. CONCLUSION

This paper aims at improving the safety of sky divers and pilots by guiding a parachute system autonomously. The main contributions are focused on auto activation system, auto guidance system and smart destination finder algorithm. This system can also be used to drop unmanned cargo to a desired location autonomously. The cost effectiveness is also one of the advantages. This system is low cost yet effective and can be life saving during emergency. This design has a lot of scope in future as there is chance for improvement and developing a robust system. We can use Augmented Global Positioning System (AGPS). To estimate the current location which reduces the error? We can also use multiple sensor data fused together to get a better heading. The data of the magneto meter can be faulty at times due to its miss alignment which can be compensated by using an accelerometer.

REFERENCES:

1. C. Peterson. The Fluid Dynamics of Parachute Inflation. *Annual Review of Fluid Mechanics*, 2002.
2. Daniel Preston. Steerable parachute control system and method, 2002. [3]Willard D Carpenter. Velocity/altitude sensing automatic parachute release, 1968.
3. Xinglong Gao, Qingbin Zhang, and Qiangang Tang. Parachute dynamics and perturbation analysis of precision airdrop system.*Chinese Journal of Aeronautics*, 2016.
4. David Woods and Erik Hollnagel. Automation Surprises. In *Joint Cognitive Systems*. 2010.
5. Richard Benney, Andrew Meloni, Andy Cronk, and Robyn Tiaden. Precision Airdrop Technology Conference and Demonstration 2007. 2012.
6. David Carter, Sean George, Phillip Hattis, Leena Singh, and Steven Tavan. Autonomous Guidance, Navigation and Control of Large Parafoils. 2012.
7. Henry D. Scott. *Low Cost Parachute Guidance, Navigation and Control*. PhD thesis, Naval Postgraduate School, 1999.
8. Al-Madani, Basem, Marius Svirskis, Gintautas Narvydas, Rytis Maskeliūnas, and Robertas Damaševičius. "Design of fully automatic drone parachute system with temperature compensation mechanism for civilian and military applications." Journal of Advanced Transportation 2018 (2018).

9. C. H. Poh andC. K. Poh, “Radio Controlled “3DAerobaticAirplanes” as Basis for Fixed-Wing UAVs with VTOL Capability,” Open Journal of Applied Sciences, vol. 04, no. 12, pp. 515–521, 2014.
10. L.S. Shyu and Y. C.Hsiao, “Mini UAV design and manufacture with bungee launched / Parachute recovery,” Applied Mechanics and Materials, vol. 610, pp. 97–100, 2014.