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Bird Strike: Detection and Avoidance System

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Abstract: A bird strike is defined as a collision between bird and an aircraft which is in flight, take-off or landing. Bird Strike is a common phenomenon and can be a significant threat to aircraft safety. Significant damage may be caused to the aircraft structure and especially engine section which then, can be responsible for the loss of thrust following the ingestion of birds. This has resulted in a number of fatal accidents especially in single engine aircraft. Bird strikes may occur during any phase of flight but are most likely to take place during take-off, initial climb, approach and landing stages. Since most birds fly mainly during the day, most bird strikes occur in broad daylight conditions. To detect and avoid the bird before the strike, various types of methods and mechanisms are used on ground level, but in this project, we are proposing a technique of detecting an incoming bird towards the aircraft using IR Camera, image processing technique, microcontroller and acoustic device that would trigger a noise which will scare the bird away thereby avoiding an impact. The complete system of detection and acoustic signal generation is proposed to be installed on the aircraft.
Keywords: Acoustic Device, Bid Strike, IR Camera, Image Processing Technique, Subsonic Aircraft.

I. Introduction

A. History and Incidents

The Federal Aviation Administration estimates bird strikes cost US aviation 400 million dollars annually and have resulted in over 200 worldwide deaths since 1988. In the United Kingdom, the Central Science Laboratory estimates that worldwide, the cost of bird strikes to airlines is around US$1.2 billion annually. [1]

The first reported bird strike was by Orville Wright in 1905. According to the Wright Brothers they flew 4,751 meters in 4 minutes 45 seconds, four complete circles. Twice passed over fence into Beard's cornfield. Chased flock of birds for two rounds and killed one which fell on top of the upper surface and after a time fell off when swinging a sharp curve. [2]

The 1st recorded bird strike fatality was reported in 1912 when aero-pioneer Cal Rodgers collided with a gull which became jammed in his aircraft control cables. He crashed at Long Beach, California, was pinned under the wreckage, and drowned. [3]

The greatest loss of life directly linked to a bird strike was on October 4th, 1960, when a Lockheed L-188 Electra, flying from Boston as Eastern Air Lines Flight 375, flew through a flock of common starlings during take-off, damaging all four engines. The aircraft crashed into Boston harbour shortly after take-off, with 62 fatalities out of 72 passengers. Subsequently, minimum bird ingestion standards for jet engines were developed by the FAA. [4]

On January 15th, 2009, US Airways Flight 1549 from LaGuardia Airport to Charlotte/Douglas International Airport ditched into the Hudson River after experiencing a loss of both turbines. It is suspected that the engine failure was caused by running into flock of geese at an altitude of about 975m (3,200 feet), shortly after take-off. All 150 passengers and 5 crew members were safely evacuated after a successful water landing (Ditching). On May 28th, 2010 the NTSB published its final report into the accident. [5]

B. What are Bird Strikes?

A bird strike, bird ingestion, bird hit or Bird Aircraft Strike Hazard (BASH) is a collision between an airborne animal with the aircraft. The term is also used for bird deaths resulting from collisions with structures such as power lines, towers and wind turbines. Bird strikes may occur during any phase of flight but are most likely during the take-off, initial climb, approach and landing phases due to the greater numbers of birds in flight at lower levels. Since most birds fly mainly during the day, most bird strikes occur in daylight hours. [6]

A tentative and probably conservative estimate of US$1.2 billion per year in damage and delays is the outcome of this calculation. The costs of bird damage are evaluated relative to the ability of managers to pay for bird control programs and the derived benefits thereof. Reasons for the industry's failure to invest further to reduce the costs of bird strikes are examined.

Fig. 1.1: Bird strike at the nose and the wings of the Aircraft

C. Why do Bird Strikes happen?

Large flocks of birds are hazardous to aircraft, and unfortunately birds enjoy the habitat around many busy airports. Because airports are placed on the fringe of large urban centers, they frequently have large tracts of unused, undeveloped land surrounding them as noise and safety buffers. It is that undeveloped land that is attractive to birds, particularly as suitable habitat shrinks due to urban expansion. At the same time, the general bustle of the airport often discourages large predators, giving birds a safer sanctuary.

Airports provide a wide variety of natural and human-made habitats that offer food, water and cover. Many airports are located along migratory routes used by birds. One of the first steps in reducing bird hazards is to recognize these attractants. Several attractants acting in combination are responsible for the presence of birds and their behavior at an airport. Many airports have inadequate garbage disposal systems that permit access to various food items. [6]

D. Effect of Bird Strikes on Aircraft

In cases such as smaller fixed wing aircraft and helicopters, windscreen penetration may result in injury to pilots or other persons on board and has sometimes led to loss of control. Although relatively rare, a higher altitude bird strike to a pressurized aircraft can cause structural damage to the aircraft hull which, in turn, can lead to rapid depressurization. A more likely cause of difficulty is impact damage to extended landing gear assemblies in flight, which can lead to sufficient malfunction of brakes or nose gear steering systems to cause directional control problems during a subsequent landing roll. A relatively common but avoidable significant consequence of a bird strike on the take-off roll is a rejected take off decision which is either made after V1 or which is followed by a delayed or incomplete response and which leads to a runway excursion off the end of the departure runway. Jet engine ingestion is extremely serious due to the rotation speed of the engine fan and design.

Bird strikes can damage vehicle components or injure passengers. Flocks of birds are especially dangerous, can lead to multiple strikes and damage. Depending on the damage, aircraft at low altitudes or during take-off and landing often cannot recover in time. US Airways Flight 1549 is a classic example of this. The engines on the Airbus A320 used on that flight were torn apart by multiple bird strikes at low altitude. There was no time to make a safe landing at an airport, forcing a water landing in the Hudson River. (Fig. 1.1, 1.2)[6]

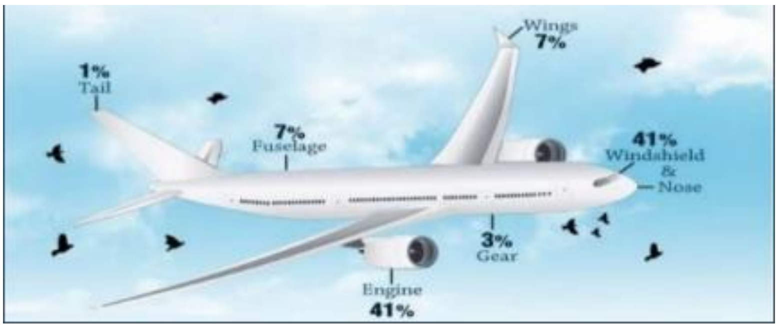

Fig. 1.2: Areas of the aircraft prone to Bird Strike

II. Objective

The nature of aircraft damage from bird strikes, which is significant enough to create a high risk to continued safe flight, differs according to the size of aircraft. Small, propeller-driven aircraft are most likely to experience the hazardous effects of strikes as structural damage, such as the penetration of flight deck windscreens or damage to control surfaces or the empennage. Larger jet-engine aircraft are most likely to experience the hazardous effects of strikes as the consequences of engine ingestion.

Complete Engine failure or serious power loss, even on only one engine, may be critical during the take-off phase for aircraft which are not certificated to 'Performance A' standards.

We intend to develop a comprehensive bird avoidance system which senses an approaching bird using optical / IR camera and as per the estimated flight path of both the bird and the aircraft, triggers an acoustic signal to scare the bird away from the flight path of the aircraft / the pilot can also deviate from his flight trajectory if the situation permits. Being an active system, it is an effective anti-bird / bird avoidance system that would be a first of its kind on flying aircraft

III. Existing Systems

Bird distress signals: are an effective way of dispersing species that cause these problems. Speakers mounted on a car emit the sounds of up to 20 different species, operated by a driver using a tablet-style device.

A Chicken Gun: is used to test the durability of aircraft windscreens and engines. A thawed chicken is fired out of the gun using compressed air, in an effort to simulate the impact of a bird hitting the plane in flight.(Fig. 3.1)

Lights on the aircraft: could be used to increase their visibility to birds. The idea is to manipulate the characteristics of the light by varying the pulse rates and wavelengths in the electromagnetic spectrum and tune these changes to specific bird species. The lights would provide an earlier warning so the birds can detect and avoid the aircraft. Some of these changes to the light might be imperceptible to humans. (Fig. 3.2)

Fig. 3.1: Chicken Gun used to driveaway the birds at an Airport

Fig. 3.2: Light System on an Aircraft

The Dutch air force radar: is a bird detecting radar which is small and mobile, and technology has come on in the last 10 years, but they can't yet identify the species or numbers.There are numerous solutions to the problem of keeping birds away from airports. 100% protection is not possible. Therefore, it is necessary to professionally manage the bird strike risk in an affected area. This can be implemented with Bird Detection and ORM (Operational Risk Management).

MERLIN Bird Radar: The First Fully Automatic Radar Solution.
Modern Radar Technology: The MERLIN radar system is the first professionally used system for the automatic detection and monitoring of bird movements. S-band radar technology makes the radar operable in all weather conditions and 24/7 operable. Specially developed software analyses the radar raw data using typical flight patterns and automatically classifies the risk to runways. Fully automatic feedback via monitors to the airport tower and bird control personnel is possible. (Fig. 3.3) [7]

Habitat Management: The attractiveness of locations determines the strength of a bird population. This can be influenced by specific measures e.g. shorter vegetation, the netting of water reservoirs, passive bird control measures on buildings and falconry. (Fig. 3.4)

Use of Predators: Often birds can only breed because hostile predators are missing. The use of saker, peregrine and other falcons with various teams distributed over the day can create hostilities in the affected territory.

Acoustic Methods – Predator Cry Systems: Birds react to acoustic stimuli. This is used by predator cry – and blank firing systems. These imitate predator and the warning cries of the birds to be controlled. The habituation effect is reduced by modulating the cries, changing frequencies and intensity.

Acoustic Methods – Directional Acoustic Systems: With the Long-Range Acoustic Device acoustic signals up to 150 dB can be directly beamed up to 1,500 meters. It transmits bird cries and other noises that disturb birds.LRAD is a product for the professional, in which only trained operators are allowed to use it. The LRAD is usually combined with a laser (LDU).

Fig. 3.3: MERLINBird Radar System

Fig. 3.4: The Predator Birds from left – Kestrel and PeregrineFalcon Bird

Bird Robots: Predators can only be controlled to a certain degree and can themselves be a risk to aircraft. Therefore, flying models in the form of predators are used. These are controlled by Experienced pilots. The models are capable on long ranges and flying high. (Fig. 3.5)

Fig. 3.5: A Falcon Robot Bird

Fig. 3.6: Netting System in an Airport

Fig. 3.7: A Bird House

Netting: For historical reasons airports are often close to landfill sites. These are irresistible attractions to birds.The only one solution is the large-area netting of the landfills, and also the neighbouring reservoirs, hangars and other buildings. (Fig. 3.6)

Bird Houses: Bird Houses are used to attract birds so that they can be easily controlled and the population reduced by exchanging the eggs (in accordance with the Augsburg Model). This method is animal-friendly and highly effective in the long-term. (Fig. 3.7)

Visual Methods: Research has shown that birds perceive light at 532nm wave length particularly well. The TOM500 laser system is with its green light very effective.
The laser is only directed downwards so that it is completely safe. [8]

IV. Survey of Accidents Due to Bird

Date:	**31st March 2015**		**Date:**	**10th August 2015**
Aircraft:	CRJ – 200		Aircraft:	C – 152
Airport:	Minneapolis – St Paul International (MN)		Airport:	Ohio State University (OH)
Phase of Flight:	Climb (5,000 feet AGL)		Phase of Flight:	Take – off
Effect on Flight:	Precautionary Landing		Effect on Flight:	Aborted take – off
Damage:	Wing		Damage:	Windshield
Wildlife Species:	Bald Eagle		Wildlife Species:	Red – tailed Hawk
Comment from Report:	Right-wing leading-edge dent 20 – 24 inched long, located mid – section of right wing. Returned for inspection. Repair costs ($50,000). ID by Smithsonian, Division of Birds.		Comments from Report:	Bird circled in front of aircraft on take-off. Stuck and shattered windscreen resulting in aborted take-off.

Year	No. of adverse incidents	Down-time (hours)	Repair Costs (x $ 1 million)	Other Costs (x $ 1 million)	Total Costs (x $ 1 million)
1990	424	23,892	92	26	118
1991	483	38,521	36	19	55
1992	593	55,179	53	3	55
1993	509	141,456	46	5	51
1994	582	226,070	46	55	100
1995	655	63,052	339	148	487
1996	684	93,891	60	18	77
1997	783	180,606	61	32	93
1998	806	96,319	164	23	188
1999	979	145,649	109	21	130
2000	1,112	217,046	111	129	241
2001	977	139,314	283	39	322
2002	1,104	149,706	168	71	240
2003	998	111,602	162	43	205
2004	950	158,029	100	22	122
2005	975	85,550	263	76	339
2006	941	109,910	205	13	218
2007	979	161,772	172	33	205
2008	905	105,126	110	13	123
2009	1,185	95,777	443	17	460
2010	1,128	74,777	145	15	160
2011	1,145	81,036	267	17	284
2012	1,330	100,611	145	11	156
2013	1,444	109,457	90	18	108
2014	1,456	92,078	189	15	204
2015	1,451	69,497	203	27	229
Total	**24,478**	**2,925,926**	**4,062**	**909**	**4,971**
Mean	**941**	**112,536**	**156**	**34**	**191**

Table 4.1: Minimum projected annual losses in aircraft downtime (hours) and in repair and other costs from wildlife strike with civil aircraft, USA, 1990–2015.

V. Birds Population Trends and Patterns

Although in recent years the overall bird population has declined in Europe by over 10% the bird strike hazard for aviation has not reduced proportionally. The reason is that not all birds pose the same hazard to aviation safety, as this depends on the size of the birds and their foraging or migratory patterns. Birds may pose a threat to aviation due to their individual size or due to their tendency to fly in large flocks. It is likely that the smaller the birds are, the greater their need to travel in flocks in order to avoid predators. (Fig. 5.1)[9] [10]

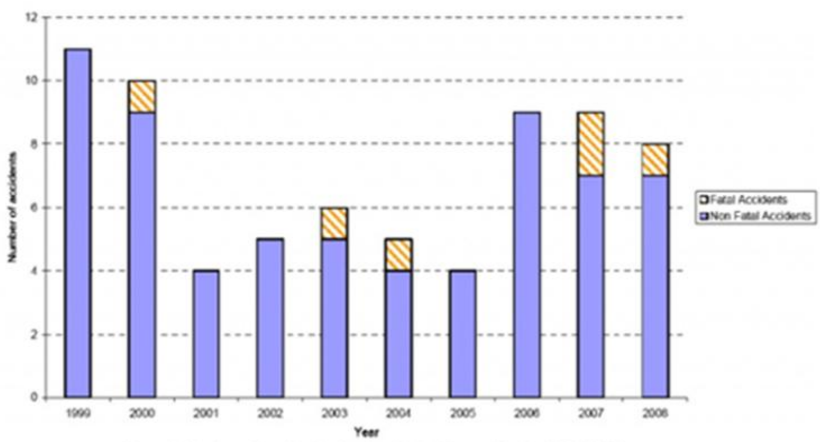

Fig. 5.1: A Graph which shows Number of Fatal Accidents vs Year (1999 – 2008)

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VI. Method Implemented to Avoid Bird Strike

A. IR (Infrared) Camera

It is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 400–700 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm).

Theory of Operation: IR Cameras work like normal cameras during daytime by using visible light reflected from the bird to capture image. Infrared energy is just one part of the electromagnetic spectrum. All objects emit a certain amount of black body radiation as a function of their temperatures. Generally speaking, the higher an object's temperature, the more infrared radiation is emitted as black-body radiation. The IR camera can detect this radiation in night time a way similar to the way an ordinary camera which works during the day time. It works even in total darkness because ambient light level does not matter. [11]

B. LRAD (Long Range Acoustic Device)

It is an acoustic hailing device developed by LRAD Corporation to send messages and warning tones over longer distances or at higher volume than normal loudspeakers. LRAD applications include means of non-lethal, non-kinetic crowd control. They have been called “Sonic Weapons”.

The LRAD's job is to produce very loud sound that is audible over relatively long distances. Normal speaker uses one rapidly moving diaphragm to make sound, but LRAD uses lots of moving devices (LRAD has array of Piezoelectric transducers). A transducer is simply a device that changes one kind of energy into another kind of energy. In this case, it changes electrical impulses into sound energy. Depending upon the Acoustic range required LRAD's devices are used. [12]

C. Installation of the devices

Installation of the any external devices or instruments on the aircraft should be done with considering some of the important aspects related to overall performance of the aircraft like effects due to additional weight of device, aerodynamic effects due to more drag and propulsive effects. If effects due to installation are minor, which can be negligible then installation can be done. As weight of the IR Camera and Acoustic device which are used is very less in weight compared to the overall weight of the aircraft and their will not be any severe effects to the overall performance of aircraft after installation.

Fig. 6.1: Placement of Camera and Acoustic Device

The Acoustic devices are placed on either side of the aircraft on the wing close to the fuselage body. We have selected nose of the aircraft as the part where we are placing our camera. Since nose is a foremost part of the aircraft, addition of external devices like cameras in our case will not severely affect the aircraft overall performance due to aerodynamic drag component. We are placing two cameras as shown in Fig. 6.1, one on the upper hemisphere (which covers the portion ahead of aircraft while climbing) and other on the lower hemisphere of nose section (which covers the bottom portion while descending).

SI NO	Aircraft	Take-off Speed (m/s)	Landing Speed (m/s)	Cruising Speed (m/s)
1	Boeing 737	68	62	260
2	Boeing 757	72	66	272
3	Airbus 320	78	70	233
4	Airbus 340	80	77	242
5	Airbus 380	78	72	252
*	**Average**	76	70	252

Table 6.1: Take-off, Landing and Cruising Speed

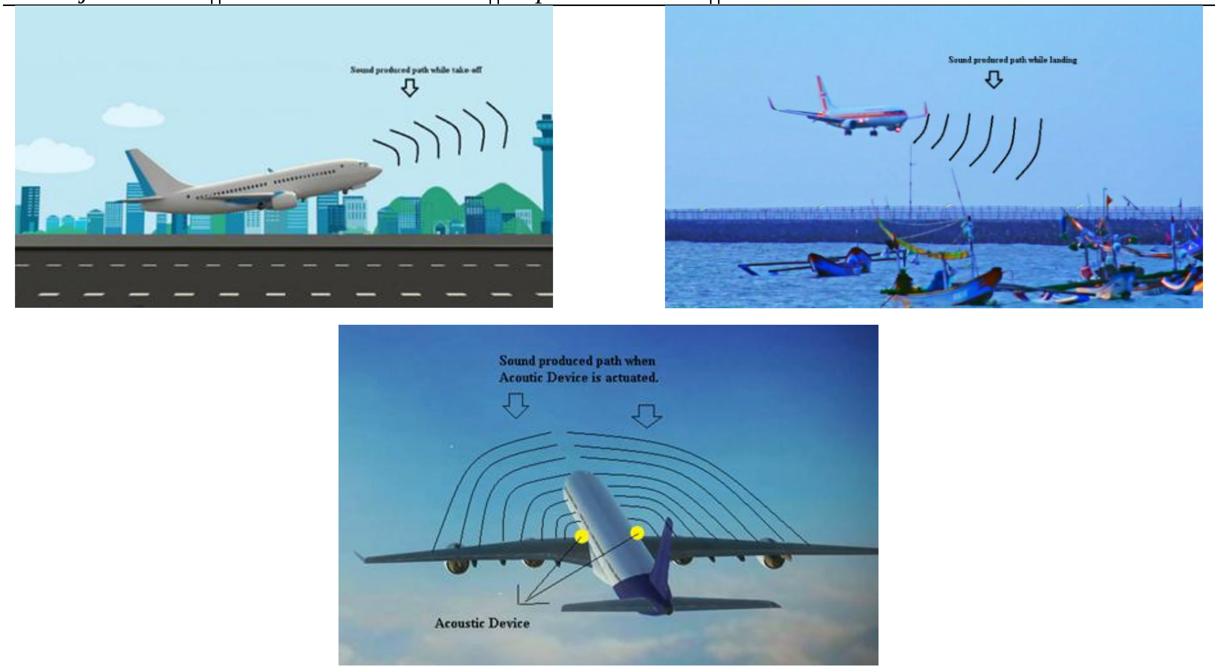

Fig. 6.2: Placement of Acoustic Device and Sound produced path when actuated.

Ex: Considering from the video captured by the camera if it is clear that there is bird at 300m distance which is flying towards the aircraft at speed of 50m/s (highest speed of Falcon bird), in normal cases the birds fly at 10m/s – 20m/s while migrating, then in next 1 sec aircraft has moved to 70m – 80m. Bird has approached towards aircraft 20m – 30m, still aircraft is 200m away from the bird, then acoustic device will actuate in next 1s. Sound travels to 340m, once the bird hears the sound, it gets disturbed and changes its path of flight away from the sound produces path.

Note: Since cruising speed is high, if we apply the same concept with Artificial Intelligence Technology, the process of identification of bird will be faster than MATLAB program. So thus, we can prevent bird strikes. The MATLAB program method can be effectively used to avoid bird strike during take-off, climb, descent and landing phases of the Aircraft.

The region of sound produced from the acoustic device will not only cover the engine but also the wings and main fuselage sections of the aircraft. The sound will be produced in such a way that the birds are capable of sensing it and getting distracted. The frequency of bird varies from different tropical regions to different species of birds are observed.

Hearing is birds' second most important sense and their ears are funnel-shaped to focus sound. The ears are located slightly behind and below the eyes, and they are covered with soft feathers – the auriculars – for protection. The shape of a bird's head can also affect its hearing, such as owls, whose facial discs help direct sound toward their ears.

The hearing range of birds is most sensitive between 1 kHz and 4 kHz, but their full range is roughly similar to human hearing, with higher or lower limits depending on the bird species. Birds are sensitive to pitch, tone and rhythm changes and use those variations to recognize other individual birds, even in a noisy flock, also uses different sounds, songs and calls in different situations, and recognizing the different noises is essential to determine if a call is warning of a predator, advertising a territorial claim or offering to share food. [13]

"Some birds, most notably Owls, also use echolocation, just as bats do. These birds live in caves and use their rapid chirps and clicks to navigate through dark caves where even sensitive vision may not be useful enough".

VII. MATLAB (MathWorks Laboratory)

It is a multi-paradigm numerical computing environment. A language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. [14]
The operation includes 3 main building blocks for an automated surveillance system.

1. Moving Object Detection
2. Object Tracking
3. Event Recognition

The detection of object in the MATLAB is done using Automatic Tracking and Segmentation of Moving Objects in Video for Surveillance Applications. In deep the case study is as described in the Fig. 7.1.

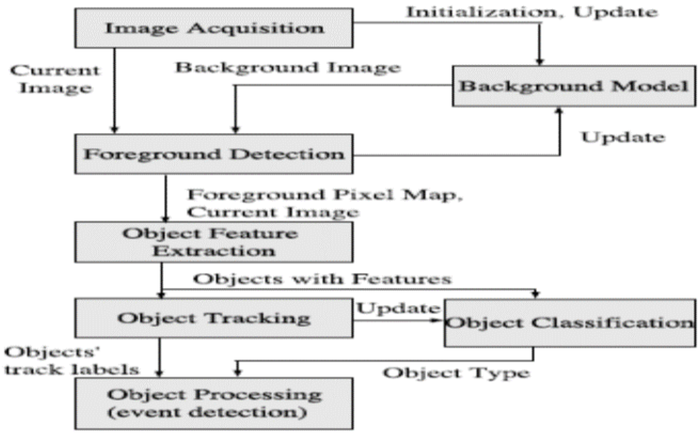

Fig. 7.1: Case study flow chart of Event Detection

A. Foreground Binary Image

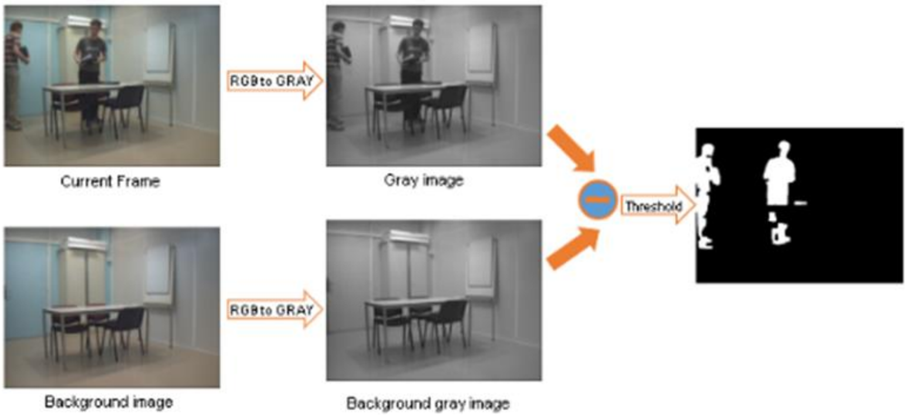

Fig. 7.2: Background Image Comparing and Subtracting

Here it is comparing the current frame (where there are 2 people standing) to the background frame (eliminating 2 people form the background), then converting the RGB (Red, Green, Blue) scale image to Grey scale image, and then using threshold value the Grey scale image is converted to black and white image or binary image along with eliminating the background which is compared with the current frame. (Fig. 7.2) [16]

The tracking process is implemented in Graphic User Interface which is a part of MATLAB. (Fig. 7.3)

B. Creating Training Folder

The MATLAB requires set of images to compare whether it is a bird or not. Here we have considered Bird and UAV which looks similar to Bird while detecting. We create a training folder under that we create Bird folder and UAV folder. We store set of Bird images in Bird folder and UAV images in UAV folder. When the object is detected in the MATLAB process, it compares with the data base that is the training folder and tells whether it is Bird or UAV. Apart from these we can detect any object and compare from data base but before comparing we have to save those images to get compared into the training folder. As here we are concerned about the Birds, we detect it from the background and eliminate other object rather than Bird to actuate Acoustic Device.

As of now we have stored limited database to run MATLAB program for particular video, hence the bird detection will be done in parallel with the video. But in normal case / real time case video captured by the camera will include so many other things like buildings, trees, vehicles, people, land, animals, other environmental things. So now to avoid the false alarm and identify only birds and nullify all other things in background, we have to trainour MATLAB process of identification by introducing more database. The program should clearly identify which is bird and which is not. (Fig. 7.4)

Since the database storage is increased, the process will take some time to understand whether it is bird or not. Hence in this case MATLAB will run slowly (there will slight delay in terms of seconds for output). But this program can be overcome by using Artificial Intelligence Technology. [15]

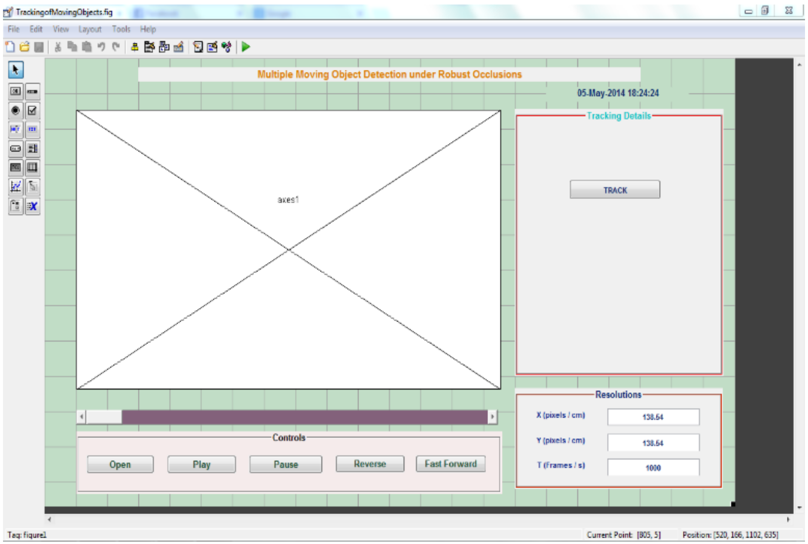

Fig 7.3: Output window of the GUI (Graphic User Interface)

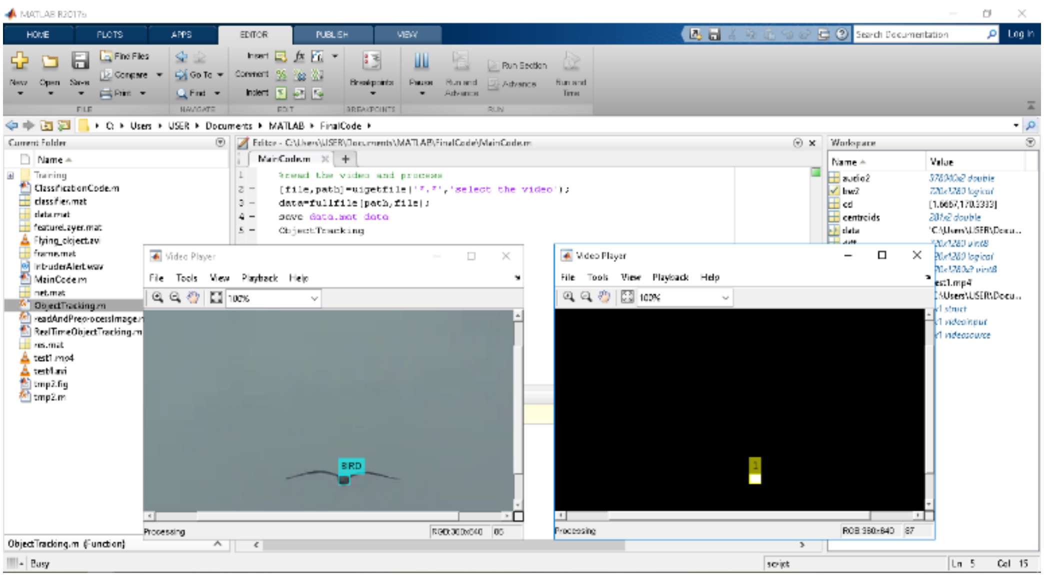

Fig. 7.4: Output Result of Bird Detection

VIII. Merits and Demerits

A. Merits

- Current methods to avoid strikes are concerned only during take-off and landing, but even there will be chances of strikes during other phases of aircraft mission flight system, i.e., climb, cruise, loiter, descent at any altitude.
- It is less expensive and only one-time installation.
- It increases overall percentage of avoidance of bird strikes compared to existing methods.
- Main advantage will be protecting not only the aircraft but also the bird's life as the current projects are carried out in keeping the concept of eco-friendly.

B. Demerits

- Avoidance can be done, under Mach Number less than 1 (M<1).

- As we are using MATLAB, the process gets slight delayed in detecting so we have to stick this idea only for the civil aircraft which can fly less than 0.7 Mach.
- We need additional Electrical power system which will actuate Acoustic Device.
- Depending upon the different altitudes we have to change the dBs of sound by knowing which birds will be probably in this altitude. Thus, we can program for different altitudes different dBs of sound can be produced but gathering the bird data takes lot of time.

IX. Conclusion

Bird strike is an important parameter in terms of aircraft safety and is jointly being confronted by airports and the airlines as any damage to the aircraft can result in catastrophic losses to human lives and damages the state economy as well. Various methods like pyrotechnics, distress signals and lights have been used extensively to prevent the damage, however all of them are short-lived since these techniques come into picture when the aircraft is in the vicinity of the airports and does not provide a long-term solution to prevent the strike in flight. In our approach we develop a method through which a bird is initially detected and the data is processed in such a way that the data matches with the database which we provide and sends out a signal so that the pilot can avoid the collision and prevent the aircraft from damage. This when applied to the aircraft using an IR camera and image processing can be used in such a way that a distress signal can be initiated so that the birds can deviate their path and the aircraft is prevented from a potential accident. We have done this idea on a relatively smaller scale using MATLAB and simulations but when applied in real time this is a sure shot winner to break away from the menace of bird strike on the aircrafts.

X. FUTURE SCOPE

The final implementation for airborne systems can utilize LINUX based codes for processing as it will be much lighter than MATLAB with respect to processing time and RAM requirements would be less. MATLAB requires complex configurations to function and is time consuming. For a given system to function with ease the processing speed has to be as less as possible which is a major hindrance, we faced in our project to be applied in real time. In future aspects in terms of technicality, methods such as artificial intelligence can be implied which enables the aspect of object tracking to a much faster response and gives the output more accurately.

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