Abstract — Nowadays most of the aircrafts are equipped with automatic landing system and they rely on Instrument landing system. Limitations of commercial control system and auto landing systems have led us to use artificial intelligence system inspired by bat's behavior to control auto landing. In order to develop such system, studies are done numerically. By using MATLAB software, the aircraft motion is simulated and developed neural network systems is expected to be trained by bats intelligence.

Keywords— Collision avoidance, bat's intelligence, auto landing intelligent system, neural networking control

1. Introduction

Landing and approaching are the most challenging stage of flight. In order to have a smooth and safe landing, the aircraft wheels must make contact with the ground in a satisfying way within the defined surface of the runway. Other factors such as six degrees of freedom of the aircraft must be attributed in the kinematics of the airplane. Commercial control theory’s limitations have left no other ways but using computational intelligence. Intelligent control systems namely neural network, derive control patterns where the regime is unknown. The fascinating phenomenon of echolocation in mammals especially bats has raised hope in different field of science such as signal processing and intelligent control among researchers to improve reliability.

Training the neural network by bats intelligence is unique method that has been proposed and the applications has been discussed here for controlling the auto pilot system. The document is organized as follow: Part 2 presents particulars of the background and information on common auto landing problems, whereas part 3 provides the model used for the simulations of aircraft flight. Part 4 defines the application of bats intelligence on training neural network. Part 5 presents discussion and results and finally part 6 is the conclusions along with ongoing work in progress and future research.

2. Auto landing problem

In conditions when visual references are not reliable enough, landing aids should be used. Hence, in almost every airport Instrument Landing System (ILS) is extensively operated which helps pilots to make decision during landing [3]. At the point of height decision, the pilot should be able to clearly observe the runway to continue the approach and proceed; otherwise the pilot should take over the aircraft. This procedure has been proven and it is reliable however, it’s still not widely applicable due to the costs involved for required on board equipment.

According to Federal Aviation Administrations’s regulations, there are certain dispersion limits levied by the environment which are: headwinds up to than 25 knots (28.75 mph); tailwinds of up to 10 knots and crosswinds less than 15 knots. Plus, a moderate turbulence and a wind shear of 8 knots per 100 ft from 200 ft to touchdown. Outside of these flight conditions, the Auto Landing System (ALS) must be deactivated and the pilot takes over. National Transportation Safety Board has reported that 36.4% of the flight safety events are due to wind disturbance [3]. Hence, having a developed intelligent ALS that operates in more flexible range of envelope would lead to safer response in wider range of conditions.

3. Equation of motion in auto landing

Although a linearized model has been used, the model responds realistically. The motion is represented by the linearized model in the vertical and longitudinal planes. The aircraft motion equations given below are used to simulate aircraft motion [1] [4]:

\[ u(t + 1) = u(t) + \Delta t \cdot Xq(u(t) - u_0) + Xw (w(t) - w_0) + Xq (q(t)) - g \cos \gamma \theta(t) \]   \( 1) \]

\[ w(t + 1) = w(t) + \Delta t \cdot Zw (u(t) - u_0) + Zw (w(t) - w_0) + Zq(q(t)) + g \sin \gamma \theta(t) \]   \( 2) \]

\[ q(t + 1) = q(t) + \Delta t \cdot Mw (u(t) - u_0) + Mw (w(t) - w_0) + Mg(q(t)) + Mg \delta E + Mg \delta T \]   \( 3) \]

\[ \theta(t + 1) = \theta(t) + \Delta \theta \]   \( 4) \]

\[ h(t + 1) = h(t) + \Delta h \]   \( 5) \]

\[ Vg = U_0 \cos \gamma + ugc \]   \( 6) \]

\[ x(t + 1) = x(t) + \Delta \sqrt{Vg} \]   \( 7) \]

\[ \omega = \text{longitudinal velocity (ft/sec), } \] \( w = \text{vertical velocity, } q = \text{pitch rate} \] (degrees/sec), \( \theta = \text{pitch angle, } h = \text{altitude (ft), } x = \text{horizontal position as negative of ground distance to desired touchdown position (ft). } \] \( \Delta = \text{0.01sec sampling interval rate. } [1] \text{The incremental elevator angle } \delta E, \text{is given by:} \]

\[ K_1(\theta(t) - \theta(t)) - K_2 q(t), \] \( 8) \]

\[ K_3(\theta(t) - \theta(t)) - K_4 q(t), h(t) \geq h_0 \]

\[ \delta T = K_5 (u_c - u(t)) + K_5 \omega u(t) \]   \( 9) \]

\[ u_T(t + 1) = u_T(t) + \Delta t(u_c - u(t)) \]   \( 10) \]

\[ h(t + 1) = h(t) + \Delta (u(t) - u(t)) \]   \( 11) \]

\[ -1.5ft/sec = \text{the altitude rate and } \theta_c = \text{the ideal elevator angle:} \]

\[ -1.5^\circ \leq \theta_c \leq 1.5^\circ \]   \( 12) \]

Autopilot and auto throttle parameters: \( K_1 = 2.8, K_2 = 2.8, K_3 = 11.5 \] \( K_4 = 6.0, K_5 = 3.0, u_0 = 0 \).

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Computer Intelligent System for Control and Collision Avoidance at Auto-landing Using the Mammal (e.g. bat) Intelligence and Signals.
The values of constants used in equations can be found below:

<table>
<thead>
<tr>
<th>Aircraft response</th>
<th>$X_U$</th>
<th>$X_W$</th>
<th>$X_Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.038</td>
<td>-0.0513</td>
<td>0.00152</td>
</tr>
<tr>
<td>$X_E$</td>
<td>0.00005</td>
<td>0.158</td>
<td>0.313</td>
</tr>
<tr>
<td>$Z_R$</td>
<td>-0.605</td>
<td>-0.0410</td>
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</tr>
<tr>
<td>$Z_W$</td>
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<td>-0.0211</td>
<td>0.157</td>
</tr>
<tr>
<td>$M_U$</td>
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<td>0.459</td>
<td>0.0543</td>
</tr>
<tr>
<td>$M_W$</td>
<td>0.593</td>
<td>0.605</td>
<td>0.0543</td>
</tr>
</tbody>
</table>

Table 1 Aircraft response parameters used for the equations.

Other parameters

- $u_e$: throttle command
- $u_l$: wind speed at 510 ft altitude
- $U_0$: nominal speed
- $\gamma$: flight path angle
- $h_f$: altitude at which flare begins
- $g$: acceleration due to gravity

Table 2 Additional parameters used for the equations of motion.

4. Bats intelligence and neural network approach

In nature, there are several animals using echolocation for purposes of collision avoidance and localization. Bats have made echo detection their primary sensory for guiding flight [8]. Coordinate mapping relation is a method that bats use to calculate all the dimensions with knowing the initial position of receivers (bat’s ears) and transmitter (bat’s mouth)[7]. As it is demonstrated in figure 1b, if the data is attained for one coordinate, others can be obtained as well. The overall reflection time ($T_r$) can be measured, however the travel time of each receiver ($R_{r1}$ and $R_{r2}$) should be found by triangular method to have a very accurate position of object. The hyperbolic linear frequency modulation used by echo locating bats would help the system to have a 3D map of environment. The equations are simulated in MATLAB software and the result is indicated in figure 3a and 3b.

$$s(t) = \text{rect}(t/T) \exp(j2\pi(f_1f_2T)/(f_2\pi f_1)) \ln(1/(f_2\pi f_1)/f_2T)$$

(13)

Frequency illuminating center is $f_c$ and bandwidth $B=(f_2\pi f_1)$

Neural network technique is used more often for intelligent control. NN works have two main phases, the learning process and pattern recognition [6].

An algorithm to find the error is developed using multilayered NN shown in figure 2d by MATLAB software, samples for different assumed values are taken and the signal helps to locate and track path way and possible obstacles. The closest one to the ideal function is closer to the bottom surface. The NN model used is shown in figure 1a, and three hidden layers with 10000 epochs are considered to train the system manually using MATLAB software and later on by considering the information obtained from bats localization. By setting initial random values for weights and knowing equation 14, predicted error is found.

$$H(s) = \text{sgn}((c_w \times x) - \text{threshold})$$

(14)

Figures 2a, 2b and 2c demonstrates NN control system at different point of training, developed in MATLAB software. It can be seen that the more system is trained the less fluctuation and error is given.

5. Results and Discussions

The emitted wave form as a function of target localization has been simulated using MATLAB software and NN is trained by the chirp signal used by bat is simulated and the short Fourier transform indicates the change in the frequency with respect of time in figure 3b.

Figure 4a and 4b, are showing the result of localization using bats signal. As it can be seen, the distance from the target and in auto landing case the runway can be identified. This data should be used to train the NN system.

6. Conclusion and further research

The NN approach trained by bats intelligence for auto landing of a commercial aircraft is discussed. The result shows that this approach could be considered as a satisfactory control of aircraft. The existing work in progress scrutinizes whether bats intelligence can help auto landing to handle wind disturbance with greater magnitude by training NN, applying actual information gained by bats localization and train the system by gained information. Considering the potential, this work can be seen as a long term project for future research which should cover two element antenna beams and signal processing and transmission of bats signal plus applying microwave signals for real life applications.

References

[7] sung-Ying Sun,Tsai, JiunkYuan