Combined Application of Kalman Filtering and Correlation Towards Autonomous Helicopter Landing.

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Abstract—**Autonomous helicopter landing is a challenging problem in the field of aerial robotics. An autonomous maneuver depends largely on two capabilities: the decision of where to land and the generation of control signals to guide the vehicle to a safe landing. Here we present a control system that enables a helicopter to land on a stationary target (landmark) on the ground. The autonomous landing control process uses visual information to control the position, height as well as the orientation of the helicopter relative to the target for a safe and accurate landing. A remote controlled helicopter is used for the landing tests. The vision system, i.e., a wireless camera is mounted on the body of the helicopter and pointing downwards. The control algorithm is designed in MATLAB which issues control signals to the remote control of the helicopter based on the actual and desired visual inputs to the computer control system. The designed strategy of control is totally dynamics free as long as the helicopter and camera hardware's are concern. The closed loop system is established through virtual feedback system having visual information. The application of kalman filter (KF) is used for controlling the position and height of the helicopter. The kalman filter is usually of high complexity but for our particular application, that uses a simple state space representation for motion model, this computational complexity is avoided. An individual controller is implemented for the orientation control based on the pattern-correlation of images.**

Index Terms—Autonomous helicopter landing, vision system, computer control, kalman filter, pattern correlation, dynamics free, virtual feedback.

I. INTRODUCTION

Safe autonomous helicopter landing is a challenging problem but an important task in the field of un-manned aerial vehicles (UAVs) to achieve high level of autonomy. The main issue in the landing problem is the knowledge of the height and proper orientation and a proper controller to govern the process. The interest in UAVs has grown enormously during the past two decades. The main reason is that small autonomous helicopters can perform tasks comparable to man-controlled and can replace the use of humans in applications in the areas, where the missions are dangerous, expensive, or impossible for a human to carry out. Autonomous un-manned small-scale helicopters can be applied in such applications as surveillance, infrastructure inspection, mined detection, search-and-rescue and so on. Such helicopters must have the capabilities of having vertical take-off and landing. Multiple landing strategies have been reported in the literature. The sensing schemes for landing can be mainly summarized in two categories. The visual sensor (cameras) only and the combination of multiple sensors. Our sensing strategy belongs to vision-only system. With recent development in camera technology and image processing hardware, it is natural to consider a vision-based solution to the problem of safe autonomous landing. The estimation of depth from image sequence using a known camera motion is important in a variety of applications of computer vision applied to robot navigation and manipulation. The algorithm designed for such estimation can be based on an online incremental fashion. Such techniques require a structure which can record the uncertainty in depth estimates and a mechanism that integrates fresh measurements with prior ones to minimize the uncertainty over time. Kalman filter provides such recursive mechanism.

Relating with the previous work on such systems, we studied [1]. The developed system is using vision and global positioning based autonomous landing of a helicopter on stationary target. Some of the assumptions were derived from here. The image processing section described in this paper is derived from [2] and [3]. All ego motion compensation techniques attempt to make an estimate of the camera motion according to some transformation model. While perfect estimates of camera ego motion can only be realized with highly non-linear and unwieldy models, robust results are achieved using simpler techniques. [4] Uses affine formulation based on the assumption that the distance from the observer to the targets is large compared to the depth of the scene. Some applications, though, require slightly more complex bilinear models [5].

In contrast with the previous work mentioned in the references, we have developed a control strategy that allows the helicopter to land on the desired position of the target (a pattern on the ground, called landmark), with proper orientation. The designed system is dynamics-free and is independent of the hardware of the helicopter and camera. The control system is based only on the images received and decisions are taken according to the reference and actual visual positions of the helicopter. This allows the system to have virtual feedback link between the helicopter and the controlling computer. As the system is hardware-independent, it is very flexible and changes can be made according to the actual parameters of the helicopter system under consideration. Another better aspect of this system is that we can easily add other future ideas according to our wishes to make the system more reliable, accurate and safe for a particular application. It is important to mention here that we use a USB based I/O card and other switching and signal conversion electronics for interfacing the controller (computer) and the remote-controller of the helicopter. The general system block diagram is shown in Fig. 1.

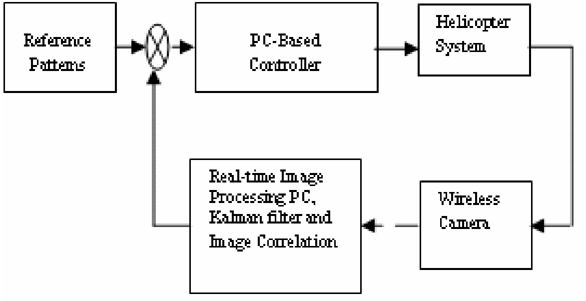

Figure 1: General Block Diagram

Some of the helicopter parameters are given in Table 1, for introducing the system under consideration. As mentioned previously such parameters are not required in our landing system as the system is free of such constraints. Also the general flow diagram of the system is shown in Fig. 2.

The paper is organized as follows. In section II, we describe an introduction to the experimental setup and the assumptions we have included. Section III, presents the general steps involved in the image processing. Section IV, describes the application of kalman filter for the position and depth control. Section V, includes the image correlation technique and its use towards the orientation control of the helicopter. In section VI, we have mentioned the simulation and experimental results. Finally, we have added conclusion and future work in section VII.

II. EXPERIMENTAL SETUP WITH ASSUMPTIONS

A detailed hardware setup in block form is shown in Fig. 3 below. Reference Patterns for the different stages of the system are stored in computer memory. Real-time processed images are received from the wireless camera through its receiver and compared with the reference patterns into the computer. Based on the results produced by the comparison the computer controller generates control commands which are sent to the USB I/O card for interfacing with the real world. The outputs produced from this card in response are further processed by ‘Signal conversion electronics’ to make it suitable for the helicopter remote control system. This part of the system has some switching mechanism so that we can easily switch whether we want to control the helicopter directly through the joy-sticks of the remote or through computer. The remote controller then transmits signals based on the PC-based controller output, and the helicopter respond in the same manner. The wireless camera attached to the body of helicopter captures images according to the actual status of the helicopter and transmits it to its receiver. The dashed arrows in the diagram show the wireless communication system. The feedback system is not connected through direct hardware, so we call it a virtual feedback system.

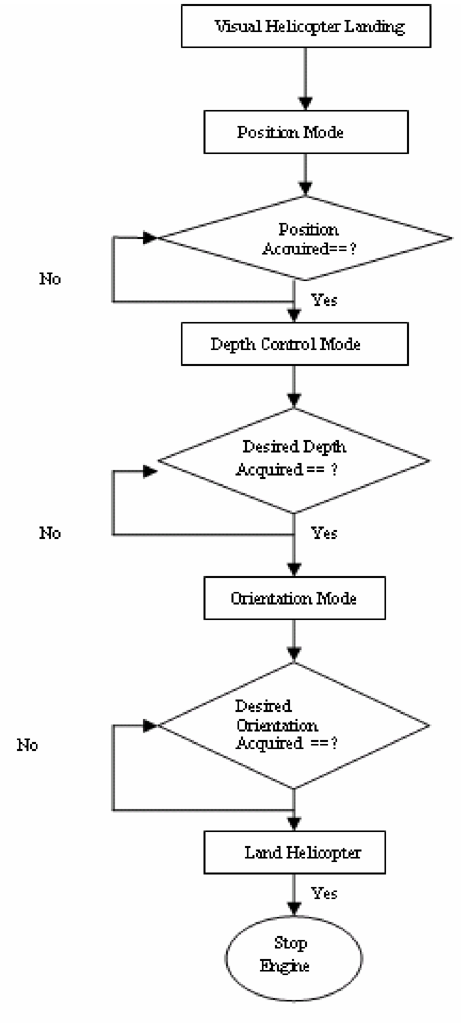

Figure 2: Flowchart of the model

Next we include the following assumptions to our system

1) The vibrations in the helicopter assembly are negligible.
2) The principal axis of the camera is aligned with that of helicopter [2], when the helicopter is perfectly horizontal.
3) The camera is perpendicular to the ground plane and pointing downwards [2].
4) The ground (here the surface on which the pattern is made) is plane.
5) The target pattern and its intensity level are different from the background. Also there are no such patterns exist in the vicinity of the search area [2].

6) The size of the target pattern in the image plane is much smaller than the image size.
7) The surrounding air blows are negligible.
8) The processing speed of the computer and that of the helicopter are matchable.

The first and second assumptions affect the accuracy of the control process. The third and fourth assumptions avoid the possibility that the camera can view the landing area through an angle. Further, to precisely differentiate the target from the background and to avoid the possibility that vision system can detect a wrong pattern to be a true one, we have added the fifth assumption. The sixth and seventh assumptions again affect the accuracy of the system. The last assumption we have added for the general control to make the system applicable in real-time environments and useful for practical applications.

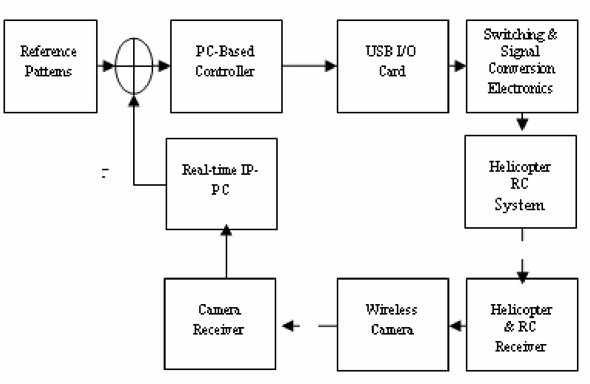

Figure 3: Hardware Block Diagram

Table 1: Helicopter Parameters

Parameter	Value
D1 : Diameter of main rotor	630 mm
D2 : Diameter of tail rotor	152 mm
W : Total weight of Helicopter	550g
Tx : Transmitter	Six Channel
Rx : Receiver	Six Channel
Gyro	Isolated Gyro
Servo	9gx4
Motor	480 Power
Speed controller	30A
Nimh Battery	DC 12V, 0.7ah
Total length of Helicopter	770 mm
Total height of Helicopter	210 mm

III. IMAGE PROCESSING

This section describes some of the preliminary actions taken for the reference (desired) position image and the actual images taken from the current positions of the helicopter. The aim of this stage is to find, extract and locate the target pattern.

A. Pattern Selection

The selected pattern is a sketch roughly similar to the shadow of the helicopter and is used as a helipad. The captured target pattern (Helipad) is shown below in Fig. 4. The circle inside the pattern is the place where the helicopter is to touch while landing. All the control processes involved in landing use the same basic shape.

Figure 4: Helipad Pattern

B. Sub_Pattern Selection

We have selected different sub-patterns from the target pattern for depth and orientation control modes of the helicopter. The selected patterns for both position plus depth and orientation modes are shown below in Fig. 5and 6, respectively.

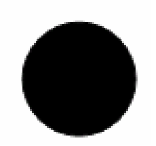

Figure 5: Position and Depth Control Pattern

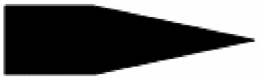

Figure 6: Orientation Control Pattern

We have shown above in Fig 6, one of the patterns used for orientation. Actually in our algorithm we use the same basic shape with different orientations e.g., tilted with angles of 15, 30, 45, 60, 330 degrees e.t.c.

IV. KALMAN FILTERING

The kalman filter is a powerful tool for doing incremental, real-time estimation in dynamic systems. It allows for the integration of information over time and is robust with respect to both system and sensor noise. The kalman filter is Bayesian estimation technique used to track stochastic dynamic systems being observed with noisy sensors. The system is based on three separate probabilistic models.

The first model describes the current state vector $X(k)$. The transition between states is characterized by the known transition matrix $\phi(k)$ and the addition of Gaussian noise with covariance $Q(k)$. The second model, the output model (measurement or sensor model) relates the measurement vector $Y(k)$ to the current state through a measurement matrix $H(k)$ and the addition of

Gaussian noise with covariance $R(k)$. The last model, states the knowledge about the system state $\tilde{X}(0)$ and its covariance $P(0)$ before the first measurement is taken. These models are expressed as:

$$X(k) = \phi(k-1)\ X(k-1) + \eta(k) \qquad (1)$$

where $\eta(k) \sim N(0, Q(k))$

$$Y(k) = H(k)\ X(k) + \xi(k) \qquad (2)$$

where $\xi(k) \sim N(0, R(k))$

The measurement and system noises are un-correlated, e.g.,

$E[\eta(k), \xi(k)'] = 0$; $E[X(0)] = \tilde{X}(0)$;

and

$$Cov[X(0)] = P(0); \qquad (3)$$

The second step in the kalman filtering is the prediction phase and can be described as:

The state estimate extrapolation:

$$\tilde{X}((k)(-)) = \phi(k-1)\tilde{X}((k-1)(+)); \qquad (4)$$

Where $(-)$ is before the measurement is taken while $(+)$ is after measurement.

And

$$P((k)(-)) = \phi(k-1)P((k-1)(+))\phi(k-1)' + Q(k-1) \qquad (5)$$

is the state covariance extrapolation.

The third and last phase is the updation which is:
state estimate updation:

$$\tilde{X}((k)(+)) = \tilde{X}((k)(-)) + K(k)[Y(k) - H(k)\tilde{X}((k)(-))] \qquad (6)$$

The state covariance updation:

$$P((k)(+)) = [I - K(k)H(k)]P((k)(-)) \qquad (7)$$

Kalman Gain Matrix:

$$K(k) = P((k)(-))\ H(k)'\ \mathrm{Inv}[\ H(k)\ P((k)(-))\ H(k)'\ R(k)\ ] \qquad (8)$$

Tracking a moving ball by a ping-pong playing robot, the state vector consists of the ball position and velocities and is $[x, y, z, x', y', z', 1]'$. Where x, y are parallel to the image plane and z aligned with the optical axis.

The transition matrix can then be modeled as

$$\phi(k) = \begin{pmatrix} 1 & 0 & 0 & \Delta k & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & \Delta k & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & \Delta k & 0 \\ 0 & 0 & 0 & -\beta & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\beta & 0 & -g\Delta k \\ 0 & 0 & 0 & 0 & 0 & -\beta & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Where Δk is the sample time; β = Coefficient of friction and g is the gravitational constant. The random disturbances that influence the trajectory are modeled by the process noise matrix $Q(k)$.

For our particular camera which uses orthographic projection and uses a simple algorithm to find the center of mass of the circular pattern, the sensor can be modeled by the matrix

$$H(k) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Where $H(k)$ maps the state vector to the measurement model $Y(k)$. The uncertainty in the sensed circle position can be modeled by a 2x2 covariance matrix $R(k)$.

The discrete-time block diagram of the kalman filter is shown below in Fig.7.

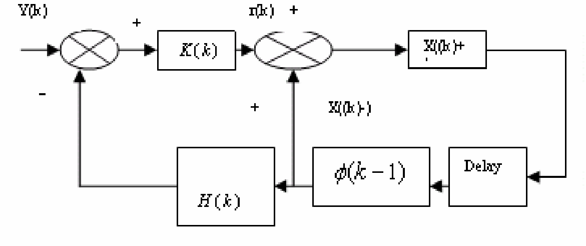

Figure 7: Kalman Filter

Position Control:

In our particular application, we are only interested in the center of the circle (x,y), the state transition matrix for state $X(k) = [x, y, x', y']'$ will be simplified to

$$\phi(k) = \begin{pmatrix} 1 & 0 & \Delta k & 0 \\ 0 & 1 & 0 & \Delta k \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

where $\Delta k = k - (k-1)$ is the one sample time. And similarly the output matrix $H(k)$ will be

$$H(k) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

We are interested in the first two rows of the above matrix as it contains the center of the pattern circular shape; the last two dummy rows are added for matrices manipulation.

The exact position of the helicopter is that the camera's optical axis must be perpendicular to the landmark at the center of the circular pattern. When the camera is exactly vertically above this center, we specify that the helicopter is exactly positioned.

The kalman filter is used to update the center of the circle at each time sample with a fresh image taken and the control signals are issued to move the helicopter until we get exact position of the helicopter.

If (x_{rp}, y_{rp}) and (x_{pp}, y_{pp}) are the centers of the desired position and position in the present-time (real-time) images respectively, then the control actions are taken on the following basis.

The ideal difference should be zero.

$$x_{rp} - x_{pp} = 0 \text{ and } y_{rp} - y_{pp} = 0 \qquad (9)$$

We keep some tolerance (errors) to simplify and speed up our system. Now if the acceptable errors are

$$e_{xp} = x_{rp} - x_{pp} \quad \text{and} \quad e_{yp} = y_{rp} - y_{pp} \qquad (10)$$

Then the required conditions are

$$\lim_{t\to\infty}(x_{rp} - x_{pp}) = e_{xp}(t) \text{ and } \lim_{t\to\infty}(y_{rp} - y_{pp}) = e_{yp}(t) \qquad (11)$$

The above idea is taken from [5]. For precise position control, the algorithm is designed in such a way that it issues commands to the remote-control system which makes the helicopter movements slow and slow with time as it is approaching helipad.

Depth Control:

After acquiring the correct position of the helicopter, e.g., the helicopter is now exactly vertically above the center of the circular part of the landmark, the next issue in the landing problem is the depth control of the helicopter.

Through manual calibration, a linear equation is derived which relates the radios of the circle in the image plane and the height of the helicopter at that particular instant. The linear equation is:

$$h = a \times R + b \qquad (12)$$

Where R is the radios of the circular pattern in the image when the helicopter is at height h from the ground. a, b are calibration constants and can be easily calculated using multiple values of R,s and their corresponding h,s when manual calibration is performed. The values of a's obtained at each instant are then averaged to obtain an optimal value of a. This optimal value is then putted back into the equation and more practical value of b is calculated.

Now a three step algorithm is applied in matlab to find an estimate of the radios of the circular pattern. If the center of the circle is (x_c, y_c) and the coordinates of one of the point lies on the the circumference of the circle is (x_d, y_d), then the radios will be:

$$R = ((x_d - x_c)\wedge 2 + (y_d - y_c)\wedge 2)\wedge 0.5; \qquad (13)$$

A single dimension kalman filter is then applied which adds the noises and the previous estimate of the radios to find a more accurate estimation of the radios at a particular sample time. The value of the updated radios is then putted back into the calibration equation to find the height of the helicopter at a particular instant. The recursive process is repeated until we acquire a desired height of the helicopter above the landmark.

The helicopter is now properly positioned and its desired height is now achieved. The last required issue of landing is the proper orientation control of the helicopter.

V. CORRELATION AND ORIENTAION CONTROL

A Pattern Selection

The correlation of two functions $f(x,y)$ and $h(x,y)$ is defined as (mentioned in [3])

$$f(x,y)oh(x,y) = (1/MN)\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f^*(m,n)h(x+m,y+n) \qquad (14)$$

Where 'f^*' denotes the complex conjugate of 'f'. With real functions (images) we have $f^* = f$. Let $F(u,v)$ and $H(u,v)$ be the fourier transforms of the above two functions respectively, then the correlation theorem states that

$$f(x,y)oh(x,y) \Leftrightarrow F^*(u,v)H(u,v)$$

and

$$f^*(x,y)h(x,y) \Leftrightarrow F(u,v)\,o\,H(u,v) \qquad (15)$$

Matching by Correlation: - To find the matches of a sub-image $w(x,y)$ of size $J \times K$ within an image f (x,y) of size $M \times N$ where $J \le M$ and $K \le N$, we have

$$c(x,y) = \sum_s \sum_t f(x,y)w(x+s,y+t) \qquad (16)$$

for $x = 0,1,2,...,M-1$; $y = 0,1,2,...,N-1$

The correlation function in (16) has the disadvantage of being sensitive to changes in the amplitude of f and w. For example, doubling the values of f doubles the value of $c(x,y)$. To overcome this problem, we use matching via correlation coefficient, which is defined as

$$\gamma(x,y)=\frac{[\sum_{s}\sum_{t}\{f(s,t)-\overline{f}(s,t)\}\{w(x+s,y+t)-\overline{w}(s,t)\}]}{\sqrt{[\sum_{s}\sum_{t}\{f(s,t)-\overline{f}(s,t)\}^{2}+\{w(x+s,y+t)-\overline{w}(s,t)\}^{2}]}} \tag{17}$$

where $-1\leq \gamma \leq 1$ and $x=0,1,2,...,M-1$;
and $y=0,1,2,...,N-1$

$\overline{w}$ is the average value of the pixel in w (computed once only), $\overline{f}$ is the average value of f in the region coincident with the current location of w. Such a correlation is called normalized correlation.

Considering the same idea of normalized two-dimensional cross correlation, we have implemented our strategy.

B Thresholding

To find a more accurate center of the pattern from the band of center points, we use thresholding to make the center more visible. The images after correlation (of the pattern with one of its correlated image) and its thresholded result are shown below in Fig. 8. (a) and (b) respectively.

Figure 8: (a) Corr-Image (b) Corr-Threshold Image

C Image partition and coordinates of maximum intensity level

The image shown in Fig. 8 (b) has been divided in four equal parts. The purpose of this partition is to save the processing time while searching the point of maximum intensity in the image. For example, if the point of maximum intensity falls in the first portion of the image, we save 75 percent time when we process the whole image.

As stated above that the shown pattern for orientation in Fig. 6, is the desired orientation of the helicopter. To estimate the present-time orientation of the helicopter, the same pattern viewed from different angles are taken and temporarily stored for matching with real-time images captured.

We use divide and conquer rule to obtain an accurate orientation of the helicopter with minimum processing time. In the first step of divide and conquer rule, the tilted patterns at angles 30, 60, 90, 330 degrees are compared (through correlation steps) with the real time image. By doing so, we can find the present-time orientation of the helicopter likely to be within a band of 30 degrees. In the next step of divide and conquer rule, the oriented patterns within the 30 degrees band with a difference of 5 degrees in successive patterns are compared with the real-time image. In this way we reach the orientation of the helicopter within a minimum accuracy of maximum 5 degrees. In the third step where the 5 degrees band is divided into further five angle patterns and compared, we finally get the exact orientation of the helicopter. Once the present orientation of the helicopter relative to the landmark is extracted, a simple proportional controller is implemented to decide the direction and speed of rotation of the helicopter to bring it back to the desired orientation.

VI. SIMULATION AND EXPERIMENTAL RESULTS

A series of computer simulations and practical experiments were carried out. We ran the MATLAB based algorithm many times and observed the behavior of the helicopter in response to different commands produced by the software. The output of the USB I/O card was not compatible with the remote-control system of the helicopter, so for properly interfacing we added interfacing electronics for both translational and rotational controls of the remote-control system. The helicopter we used was operating through a 12V DC battery. For assumption seven in section II, we performed the experiments in an isolated big hall free from electrical appliances producing air blows.

During the development of the software we faced several problems in the landing process, but we were making changes continuously and finally we achieved a stable operation of the system.

After stabilizing the system, we performed many experiments and stored the results. The procedure of each experiment was as follows.

Initially we allow to fly the helicopter in the air (within the specific area) and then was brought to a position where the landmark was seen in the camera field of view. We then switched the system to autonomous landing system keeping the height of the helicopter in the limits where the camera can distinguish the landmark from the background. This height was observed to be maximum of 20 feet.

Now considering the position-mode, the system dynamics are given in section IV. Varying the sample time step and initializing the kalman filter with the matrices:

$$R(0)=\begin{pmatrix}0.28 & 0.24\\ 0.24 & 0.24\end{pmatrix}$$

$$Q(0)=0.01\times eye(4); \quad and \quad P(0)=100\times eye(4);$$

The initial estimate for the state vector was chosen with the center point of the image for the center of the circular pattern. The resolution of our camera was 320 by 240 in horizontal and vertical directions. So the initial state vector becomes

$X(0)=[160 \quad 120 \quad 0 \quad 0];$

The above initialization is then applied to the kalman filter. Real-time images are taken and the center of the circular pattern is updated each time. Based on the difference between the reference center point and the estimate obtained by the kalman filter, the helicopter is moved to the new position in the air to minimize the error between the two. A pictorial view showing the convergence of the center point towards the desired one is shown in Fig. 9. The corresponding errors in x and y coordinates and its convergence to zero errors with time are shown below in Figures 10 and 11 respectively.

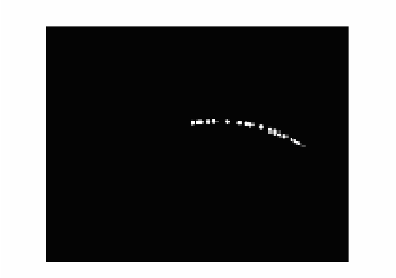

Figure 9. Flow of position-Pattern in Position Mode

For the height control mode, the relation between height and radios of the circular pattern in images is obtained from manual calibration (observation) which has the linear shape shown in figure 12 below.

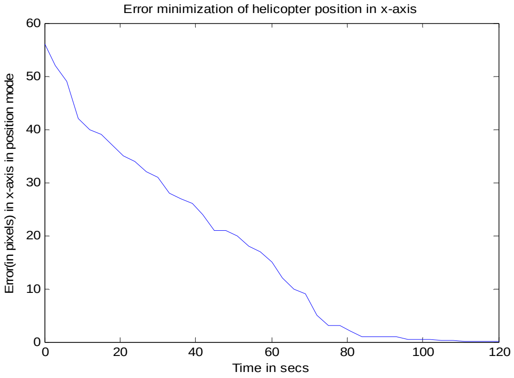

Figure 10

The values of constants a and b are found as -0.1556 and 16.556 respectively.

For the last phase of the landing process, the orientation control, we applied the image correlation technique explained in the earlier sections, and the results found are plotted.

The Fig. 13 shows the initial step for finding an estimate of tilted angle at which the helicopter is displaced from the required orientation. The maximum orientation (80%) occurs at 150 degrees angle and the nearest match is 65% at 120 degrees, which shows that the actual helicopter is oriented somehow between 150 and 120 degrees and near to 150 degrees. It shows that the helicopter is presently disoriented of about 150 degrees from the desired orientation.

Next, in the second phase of divide and conquer rule, we check the helicopter orientation with orientation patterns tilted between 120 and 150 degrees to find a more accurate result. The corresponding plot is shown in figure 14. In this step we reach to the conclusion that the orientation is between 135 (68% match) and 140 (85%) degrees and very near to 140. Doubt is still there about the correct orientation of the helicopter as we have 140-135=5 degrees band where the orientation is still to be find out. At this stage we reached an accuracy of ±4 degrees.

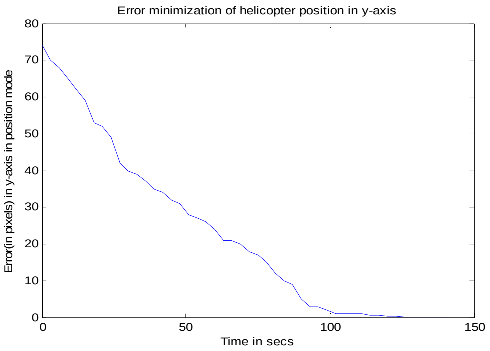

Figure 11

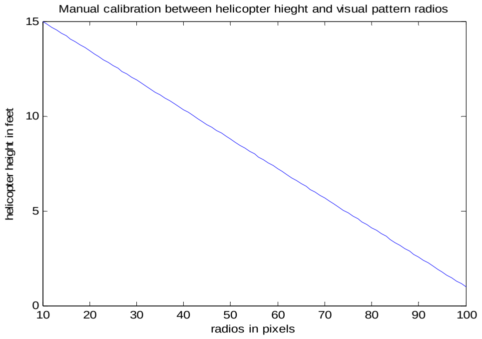

Figure 12: Linear Relation b/w Helicopter height and Pattern radius

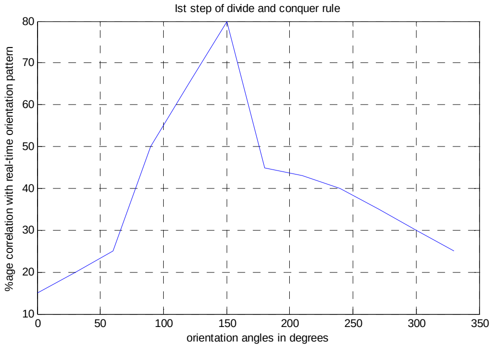

Figure 13: 1st step of divide and conquer rule showing maximum correlation at 150 deg

In the third and final stage of the above rule we further divided the band between 135 and 140 degrees in to a step of 1 degree. The plot is shown in Fig. 15 below. A 100% correlation match occurs at 138 degrees. So the final and exact orientation of the helicopter is displaced through an angle of 138 degrees from the desired one. A simple proportional controller is then implemented to decide the direction and speed of rotation to relocate the helicopter so that it brings the helicopter to the optimal orientation relative to the landmark on the ground.

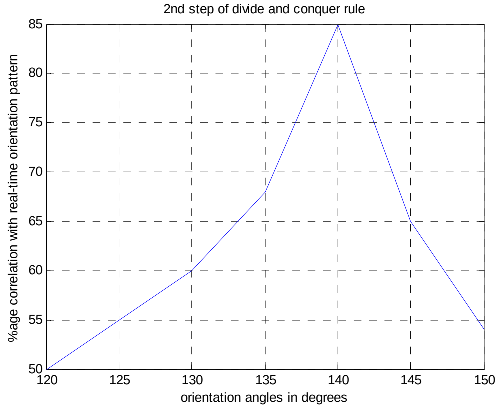

Figure 14: 2nd step of divide & conquer rule showing maximum correlation at 140 deg

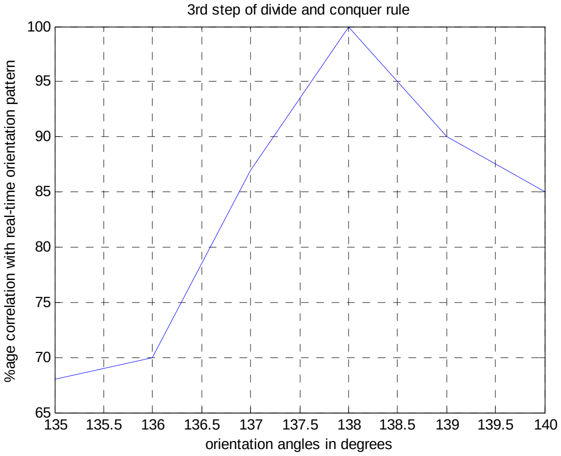

Figure 15: 3rd step of divide & conquer rule showing maximum correlation at 138 deg

VII. CONCLUSION AND FUTURE TRENDS

So far this paper is concerned we have worked out to design and implement a real-time vision-based target detecting and precise landing of a helicopter. The strategy implemented here is independent of the dynamics of the helicopter. As stated above, it is also very stable, flexible and produces no errors at the end. We have added several assumptions, such that the target is stationary and places on a planer surface. Also we made the environment free of air blows.

Now we have planned our future strategies to work out some other issues to modify our present design. In future we will work out to minimize the assumptions made in this paper and will make the target movable both vertically and horizontally. Finally we will proceed to work on tracking an unmanned helicopter for precise landing applicable to most of the real time problems.

REFRENCES

[1] Srikanth Saripalli, Gaurav S. Sukhatme and James F. Montgomery, “Vision-based autonomous landing of an unmanned aerial vehicle,” In IEEE international conference on robotics and automation, Washington D.C., May 2002, pp2799-2804.

[2] Rafael C. Gonzales and Richard E. Woods, “Digital Image Processing”, Second Edition, Dorling Kindersley (India) Pvt. Ltd, 2002.

[3] Rafael C. Gonzales, Richard E. Woods and Steven L. Eddin, “Digital Image Processing Using MATLAB”, Prentice Hall, First Edition, September 2003.

[4] I. Cohen and G. Medioni. “ Detection and Tracking of Objects in Airborne Video Imagery, In CVPR 98.

[5] B. Jung and G. Sukhatme, “Detecting moving objects using a single camera on a mobile robot in an outdoor environment, “ In international conference on intelligent autonomous systems, March 2004.