

Expanding Small UAV Capabilities with ANN

A Case Study for Urban Areas Inspection

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ABSTRACT

Aims: Autonomous Unmanned Aerial Vehicles (UAVs) are available alternative for urban areas inspection due to its cost and safety when compared to other traditional methods. The purpose of this paper is to report the development of a system capable of analyzing digital images of the terrain and identifies potential invasion, unauthorized alterations on the ground and deforestation in some areas of special use.

Study design: The project was developed in collaboration between researchers in the context of the master's program in Science and Technology of Computation of Federal University of Itajuba.

Place and Duration of Study: Institute of Mathematics and Computation and Institute of Advanced Studies, between March 2012 and July 2013.

Methodology: The Images are captured by a camera coupled to an autonomous helicopter, which flight around the area. For the processing of the images an artificial neural network technique called Kohonen SOM (Self Organizing Map) will be used. The processing is actually a set of steps that seek to collate the final common characteristics of a given image.

Results: The Kohonen SOM allows grouping the pixels of an image with similar characteristics. In the case of this work, the pixels become widespread in two classes - white and black. After processing, there is a new output image with the colors rearranged. The same process can be used for finding faults in transmission lines in all three spectrums mentioned in this article.

Conclusion: UAVs are already being used in many fields today and will certainly be largely used for urban areas surveillance and inspection. The use of the helicopter to inspect the land showed significant results especially for low vibration electric motor that provides.

Keywords: *Pattern recognition, inspection, UAV, autonomous helicopter, Kohonen SOM.*

1. INTRODUCTION

There has grown enough interest in the use of Unmanned Aerial Vehicles (UAVs) to collect information, initially in the military and more recently also in the civil sector. Due to its low cost, has increased the need to enable UAVs into missions to collect information autonomously, without human intervention.

In many countries currently it is very common to find areas of restricted use, which need to be monitored so as to ensure its integrity by avoiding invasions, deforestation, unauthorized

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29alterations on the ground and etc. The use of UAVs for monitoring has greatly increased in
30recent years, especially with the combined use of sensor data like Global Positioning System
31(GPS) and Inertial Measurement Unit (IMU) to perform the registration of the location of the
32images [1, 2]. Last decade the use of small helicopters with cameras in urban areas have
33been estuded, for example, in [3] visual sensing is used for estimating the position and
34velocity of features in the image plane (urban features like windows) in order to generate
35velocity references for the flight control.

36Given the factors described initially the use of UAV in the inspection of transmission lines
37becomes an attractive alternative, especially because the space around the transmission
38lines is restricted to such facilities, what do minimizes the risks of accidents with humans, in
39[4] a very representative work is described and many insights using mini-helicopters to aerial
40powerline inspections are discussed.

41UAVs can travel considerable distances, with higher security and much lower cost than other
42traditional means could provide, for example, the crewed helicopters. With factors like
43fatigue and tiredness due to extensive hours of work the human eye can often fail on the
44mission of detect a change in the terrain. An autonomous helicopter is able to capture
45images from different angles, and then they can be processed by a neural network, so that
46the locations with the highest probability of finding an invasions are spotted.

47Artificial Neural Networks (ANN) are based on analogy with the functioning of human brain,
48where knowledge is maintained through the connections between neurons (synapses). The
49Kohonen SOM, is a kind of competitive neural network with unsupervised learning [5]. For
50each input signal only the neuron that has the highest affinity with it will be activated, i.e., if
51the inputs of the neural network are the pixels of an image, for each pixel only one neuron is
52activated by setting the group or class that this pixel belongs. At the end of the process,
53there is a new output image with pixels grouped according to similar characteristics.

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Figure 1 - Chosen Helicopter.

57The objective of this paper is reporting a system that can analyze images of urban areas
58under special situation, and elect (through images) most likely problematic places. The
59survey currently uses crewed helicopters and is made by human eye analyses, which has a
60high cost and are likely to have important failures. Images processed in this case are
61captured by autonomous helicopters, which greatly reduces the labour and process costs.

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642. MATERIAL AND METHODS

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662.1 AIRCRAFT

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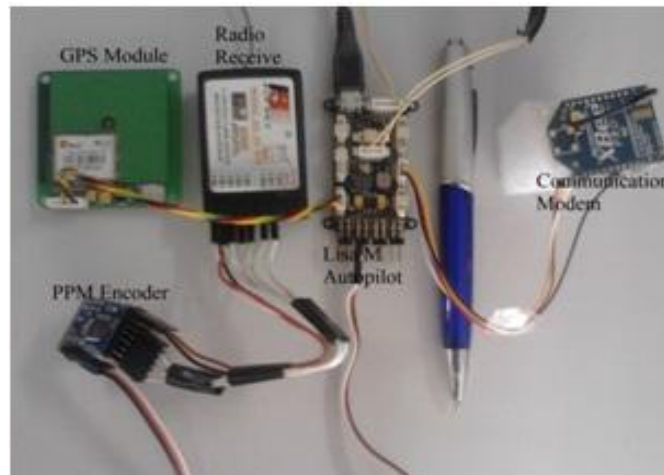
68The Mini UAV shown in Fig. 1, is a commercial RC helicopter¹ chosen for its price and
69performance, range, reliability etc. It has a 1.58m diameter rotor blade, which is powered by
70a brushless 700MX electric, and has a maximum takeoff weight of 5.2kgs. The base RC
71platform weighs 3.2kgs with batteries, sensors and flight computers.

72With the basic configuration for GPS waypoint navigation it has an endurance of 30 min. A
732.4GHz RC link is used for manual flight and a 2.4GHz wireless modem is used to transmit
74telemetry data to the ground station and operator commands from the ground station. This
75link together with the omnidirectional antennas used has a line-of-sight range of
76approximately 5km but if by any means the link is lost an automatic return home procedure
77will take command of the aircraft bringing it back to visual sight of the operator.

782.2 AUTONOMOUS AIRCRAFT

79All the sensors used for autonomous flight are included in a commercial integrated device,
80including an IMU, GPS receiver, magnetometer and barometer, see Fig. 2. The device fuses
81the sensor data with an Extended Kalman Filter to produce a filtered state estimate of
82position. The onboard flight computer uses the state estimate to generate appropriate
83commands for autonomous flight in the form of Pulse-Width Modulation (PWM) signals
84which is converted to Pulse-Position Modulation (PPM) signal through a PPM encoder
85board. These are fed to the servos via Lisa/M board. This board can select between pilot RC
86commands or flight computer commands passing through to the servos, allowing to switch
87between manual, autonomous stabilization and complete autonomous flight.

88The current control strategy is implemented using standard techniques. Proportional Integral
89Derivative (PID) loops control attitude at a high update rate, while outer loops control
90position and velocity at a lower rate. The PID gains have been tuned for airspeeds up to
9110m/s through flight trials and system identification. This control implementation provides
92reliable hover (within the error bounds of the GPS receiver), and has been used for forward
93flight with airspeeds of up to 18m/s. Although the controller performs well in winds with fairly
94constant speeds, it is not yet optimized for gusts and turbulence.



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Figure 2 - Hardware Embedded in the Helicopter.

1 Align Trex 700e Pro DFC price US\$ 1,550,00.

98.3 GROUND STATION

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100The software used in this project for aerial control is called Paparazzi and it is a free and
 101open-source hardware and software project [6] intended to create an exceptionally powerful
 102and versatile autopilot system for fixedwing aircrafts as well as multicopters by allowing and
 103encouraging input from the community, showed in Fig. 3. Many changes were made in its
 104code for supporting our helicopter. The Paparazzi project includes not only the airborne
 105hardware and software, from voltage regulators and GPS receivers to Kalman Filtering code,
 106but also a powerful and ever-expanding array of ground hardware and software including
 107modems, antennas, and a highly evolved user-friendly ground control software interface.

108The versatile Paparazzi Ground Control Station is an operator control unit ground control
 109software for micro air vehicles. It allows visualizing and controlling a micro air vehicle during
 110development and operation. With a flexible software architecture it supports multiple aircraft
 111types/autopilot projects. The purpose of the ground control station is to have a real-time
 112monitoring of an UAV[7].

113It allows the user to change in-flight parameters such as the throttle speed, altitude and
 114others. Not only that but it shows flight information like batteries level, current altitude,
 115ground speed, air speed and the top view map. With a simple mouse click the user can
 116change a waypoint location or switch to some other pre-defined route. Figure 3 shows a
 117screenshot of the interface.

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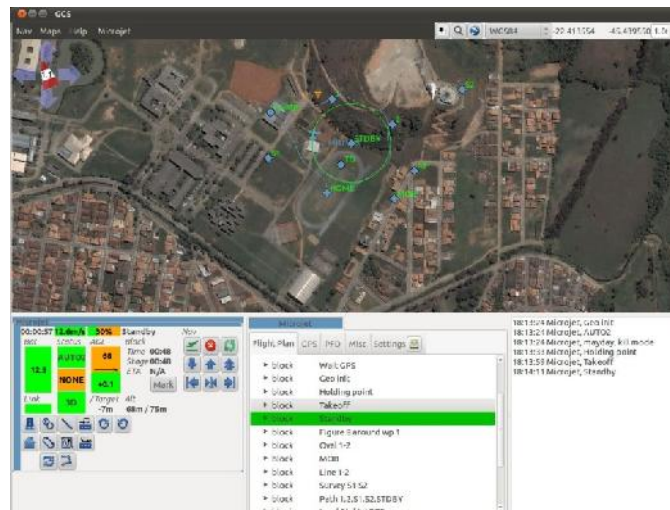


Figure 3 - Ground Control Station Interface.

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122.4 IMAGE PROCESSING

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124 A system for processing images, see Fig. 4, generally has the following parts:[8]:

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- 126 • Image acquisition: consists of a sensor to acquire the image and a second element
 127 capable of digitizing the signal, generating a digital image.

- Pre-processing: has the function to improve the image, seeking to increase the chances of success for the following procedures. Involves techniques for contrast enhancement, noise removal and region isolation;
- Segmentation: divides an input image into parts or objects. It is one of the most difficult automatic processes in image processing. The output of this stage is usually given in the form of pixels, corresponding to the boundary of a region or its constituent points;
- Representation and description: this stage of processing the data is transformed appropriately for the computational processing that follows, being stressed characteristics of interest. The process of description, also called selection of characteristics, have extracted characteristics that represent quantitative information of interest or which are fundamental in the discretion of classes and objects;
- Recognition: recognition is the process that assigns a label to an object and interpretation involves the assignment of meaning to a set of recognized objects.

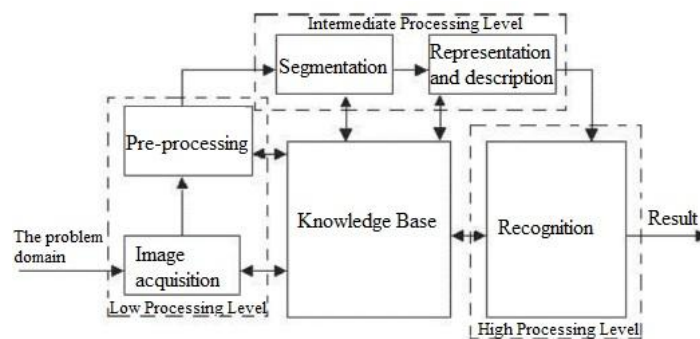


Figure 4 - Image Processing Division.

This paper presents the development of a system for classification of digital photographed images shot from a set comprising a camera² coupled to a support, provided with vibration absorbers, the whole in turn is mounted on an electric mini-helicopter. Images are georeferenced and the whole process of imaging is performed in a ground station that receives the photos sent by the mini-helicopter and saved in a hard disk for further processing. It allows one image to be inputted and generates a new output image where the pixels are grouped according to similar features.

2.5 KOHONEN SELF-ORGANIZING MAP

Kohonen Self Organizing Map (SOM) is a map or matrix with non symmetric dimension, where each element represents a neuron, [9]. Neurons are interconnected and maintained relation to each other, even influencing each other. Each neuron or set of neurons represents an output and is responsible for a particular function. This feature is analogous to the brain where different information is controlled by different parts of the brain, such as speech, hearing and vision. The artificial neural network resembles other brain aspects such as: knowledge acquisition from the environment through a learning process and connection strengths between neurons - the synaptic weights - which are used to store the acquired knowledge.

² A Sony FCB-EX980SP camera that employs a 26x optical zoom lens combined with a digital zoom function, this camera allows to zoom up to 312x.

The goal of SOM is the classification of the input data as the knowledge that neurons acquire. The topology between input and output is always kept, since the notions of neighborhood between neurons are not altered.

The synaptic weights are initialized randomly and during learning such weights will be updated at each iteration of the algorithm. The intention of this phase is to find the neuron that has the closest characteristics of the input. Thus, after a process of iteration only one neuron is activated, however their neighbors also suffer a small influence.

2.5.1 SOM Kohonen Algorithm

1. Randomize the map's nodes' weight vectors
 2. Grab an input vector
 3. Traverse each node in the map
 - 3.1 Use Euclidean distance formula to find similarity between the input vector and the map's node's weight vector
 - 3.2 Track the node that produces the smallest distance (this node is the Best Matching Unit, BMU)
 4. Update the nodes in the neighborhood of BMU by pulling them closer to the input vector
 - 4.1 $W_v(t+1) = W_v(t) + \Theta(t)\alpha(t)(D(t) - W_v(t))$
 5. Increase t and repeat from 2 while $t < \lambda$
- Where:
- t denotes current iteration.
 - λ is the limit on time iteration.
 - W_v is the current weight vector.
 - D is the target input.
 - $\alpha(t)$ is a monotonically decreasing learning coefficient.
 - $\Theta(t)$ is restraint due to distance from BMU, usually called the neighborhood function, and is learning restraint due to time [10].

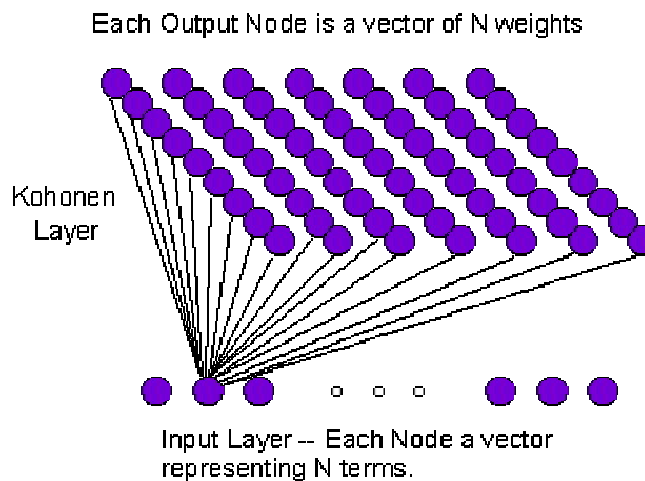


Figure 5 - Kohonen SOM Topology.

The topology of Kohonen SOM network is shown in Fig. 5. This network contains two layers of nodes - an input layer and a mapping (output) layer in the shape of a two-dimensional grid [10, 11].

1993. RESULTS AND DISCUSSION

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201A JAVA software that implements Kohonen SOM was developed. It allows one image to be
202inputted and generates a new output image where the pixels are grouped according to
203similar features.

204For the processing some parameters must be set. These parameters are linked to which
205type of sensor to capture images is being used. For example, the optimal parameters for
206images captured by an UAV are not the same as satellite images. These parameters are:

- 207 • Number of iterations: how many times the algorithm will be repeated. Typically the
208 higher the number of iterations the higher is the quality of the processing. However,
209 after a certain point the number of iteration starts to damage the quality of the output
210 image. Thus, an intermediate number should be fit so that the quality is not
211 compromised.
- 212 • Rate of learning: learning rate interferes with the updating of synaptic weights. A
213 very small learning rate requires a higher number of iterations to converge to the
214 desired result. However, a very high rate causes oscillations and also hampers
215 convergence.
- 216 • Number of neurons: each neuron represents a class, ie, a distinct characteristic. The
217 number of neurons must be placed according to how the user wants to have some
218 generalization in the grouping of neurons. The smaller the number of neurons more
219 generalist will be the grouping. A very high number of neurons will tend to cause the
220 output to copy the entry, which is not desired.
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222To test Kohonen SOM and better understand its operation some tests were made using
223aerial images of a city. Table 1 below shows the parameters used in the configuration.

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TABLE 1. KOHONEN SOM TEST

Test #	Number of Iterations	Learning Rate	Number of Neurons
Test 0	3	0.000001	2x1
Test 1	4	0.000001	2x1
Test 2	5	0.000001	2x1
Test 3	6	0.000001	2x1
Test 4	7	0.000001	2x1

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227The sequences of steps taken to implement the tests are:

- 228 1. The images were converted to grayscale.
- 229 2. An adjustment in brightness and color tone of the images was made.
- 230 3. The image is processed by the software that uses a Kohonen neural network.

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232Below we can see in the Fig. 6 to 9, an example of test number two.

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Figure 6 - Original Image Captured by the UAV.



Figure 7 - Image After the Application of Step 1.



Figure 8 - Image After Brightness Change From Step 2.



Figure 9 - Image After All 3 Steps.

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245The tests were made using only two neurons, one representing the color white and the other
246representing the color black. Steps one and two correspond to a pre-processing, which
247assist the image processing done by Kohonen SOM in step 3. The pre-processing makes it
248easier to the final process recognize which color is closer to white and which closer to the
249black. The brightness adjustment was performed using an image editor to reduce the image
250contrast.

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2524. CONCLUSION

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254Kohonen SOM allows grouping the pixels of an image with similar characteristics. In the
255case of this work, the pixels become widespread in two classes - white and black. After
256processing, there is a new output image with the colors rearranged. The same process can
257be used for finding faults in transmission lines in all three spectrums mentioned in this article.

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259UAVs are already being used in many fields today and will certainly be largely used for
260transmission line inspection, future works include but are not limited to improvements on the
261autopilot system for a better stability on gusty conditions and the usability of an airplane
262instead of a helicopter for other uses that require long and faster distances travelling.

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271REFERENCES

272

273

- 274 1. Y. Wang, R. R. Schultz and R. A. Fevig. "Sensor fusion method using. GPS/IMU data
275 for fast UAV surveillance video frame registration". IEEE International Conference on
276 Acoustics, speech and signal processing – ICASSP 2009. pp 985-988.
- 277 2. E. Semsch, M. Jakob, D.Pavlíček and M. Pěchouček. "Autonomous UAV surveillance
278 in complex urban environments". International Conference on Web Intelligent Agent
279 Technology Workshos 2009 IEEE/WIC/ACM.pp 82-85.

2803. L.O.Mejias, S.Saripalli, P.Couvera and C.S.Sukhatme. "Visual servoing of an
281 autonomous helicopter in urban areas using feature tracking". Journal of Field
282 Robotics, 23(3):185-199, 200.
2834. S. Hrabar, T. Merz, and D. Frousheger, "Development of an autonomous helicopter for
284 aerial powerline inspections," 2010 1st International Conference on Applied Robotics
285 for the Power Industry (CARPI 2010), pp. 1–6, Oct. 2010.
2865. S. Haykin, Self-organizing maps. Neural networks - A comprehensive foundation, 2nd
287 ed. Prentice-Hall, 1999.
2886. "Paparazzi Project Webpage," 2012. [Online]. Available at Internet:
289 http://paparazzi.enac.fr/wiki/Main_Page. [Accessed: 15-Jun-2012].
2907. "Paparazzi Project Webpage, Ground Control Station," 2012. [Online]. Available at
291 Internet: <http://paparazzi.enac.fr/wiki/GCS>. [Accessed: 12-May-2012].
2928. R. C. Gonzales and E. R. Woods, "Processamento de Imagens Digitais". São Paulo,
293 Brasil: Editora Edgard Blücher, 2000.
2949. A. Machado, Neuroanatomia Funcional. Livraria Atheneu, 1980.
- 295 10. M. Caudill, A little knowledge is a dangerous thing. AI Expert. pp. 8(6):16–22.
- 296 11. A. Hiotis, Inside a self-organizing map. AI Expert. pp. 8(4):38–43.