DESIGN REPORT

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Reflection and Vibration Reduction in Vision Sensors within the Wireless Sensor Network used in Unmanned Aerial Vehicle for Road Traffic Surveillance.

1 Summary of Proposal

1.1 Project Specification

The use of Unmanned Aerial Vehicles (UAV) for traffic surveillance presents a potential means by which traffic anomalies such as over speeding, drunk driving, and road congestion can be monitored actively without losing sight of the object of interest that is being tracked. Miniature drones (UAV) which are commercially available can be flown up in the air to capture images or video feeds and transmit these data back to a ground station within a wireless sensor network [1]-[2]. This provides a framework based on low-cost and low-power equipment [1]. The downside to such an approach may arise from glare caused by reflection of the sun on the cars and vibration of the drone in flight. Therefore the aim of this project is to find potential solutions to the mentioned problems by first using the Zigduino microcontroller to establish communication between multiple vision sensor nodes, and then develop and/or test methods from various on-going researches that are applicable to continuous object tracking to reduce and possibly eliminate glare and vibration. MATLAB software will be used to process the images and compare the results (other software package may also be used to complete this project e.g. OpenCV library).

1.2 Specification Review

From the preliminary hardware testing carried out on the camera, the average size of 320×240 pixel image is 12Kbytes and a 640×480 pixel image is 48Kbytes. The radio on the Zigduino board supports Zigbee communication protocol with a data rate of 250kbit/s [4]. At that speed, if the time taken is too large for continuous object tracking then the wireless module can be replaced with an 802.11b redback WiFi radio at 2Mbit/s with the risk of significant power consumption [5].

For image stabilization, a number of methods are currently used such as lens/sensor based stabilization and digital stabilization (which uses extra pixels at the border of images as a buffer to portions of the image lost due to vibration) [7]. In order to apply image stabilization in this project, only solutions that can be applied to real-time monitoring system will be used.

Glare reduction involves the use of filters, low reflection coated lenses, and lens hoods which are attached to the camera to reduce the scattering of bright light especially when the light source is not within the field of view [20]. Most of the common glare reduction techniques involve the use of extra hardware and requires the scene to be still. Therefore the focus will be on other real-time computational approaches which can fit into the road traffic surveillance use-case.

1.3 Progress Report

Thus far, extensive hardware testing were carried out to minimise the risk involved in undertaking a project that involves multiple electronic components and the software necessary for proper operation. The Zigduino boards were tested with sample codes written in the Arduino IDE and the boards worked as expected when the proper drivers were installed on the computer. Due to compatibility issues involved with using the serial UART[1] interface camera, an AMD[2] Athlon X4 640 desktop computer (3.01GHz × 4 cores with 3GB RAM) running Windows XP will also be used in the implementation of the expected goals of this project. The camera's interface pins were connected to the RS232-DB9 port (figure 1) and images were acquired by sending commands HEX codes using the camera evaluation software provided.

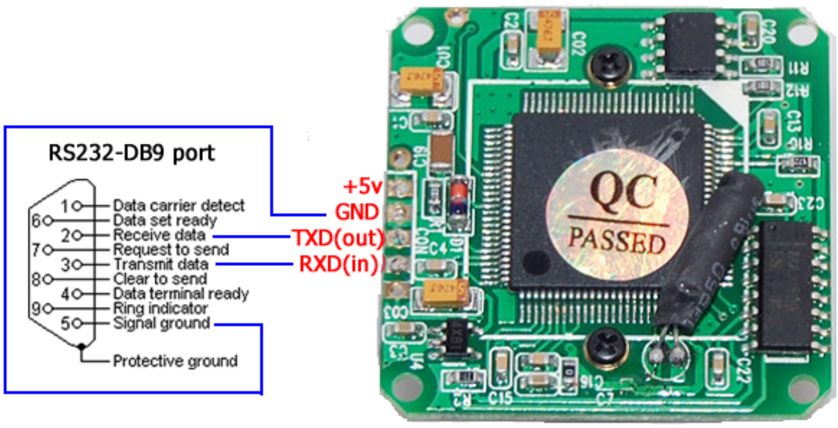

Figure 1: Camera with serial UART interface [8]

Additional time was spent on finding techniques which involves real-time computational vibration and reflection reduction methods.

[1] Universal Asynchronous Receiver/Transmitter (UART)
[2] Advanced Micro Devices, Inc (AMD)

2 Design

2.1 Design of System

The system design is comprised of three major parts:

1. The wireless vision sensor network;
2. Image vibration reduction; and
3. Glare reduction.

2.1.1 Wireless Vision Sensors Network

The Zigduino microcontroller operates at a clock speed of 16MHz and 30mA during data transmission, and 250µA when sleeping which is relatively low and acceptable for WSN [3]. The radio on the Zigduino board can support any 802.15.4 based protocol, such as Zigbee and 6LoWPAN. The Zigbee protocol supports Ad-hoc network topology with a data rate of 250kbit/s [4] [6]. In this project, two Zigduino boards A and B will be paired (as shown in Figure 2) so that image acquired from the camera module (the node) can be transmitted to the next microcontroller (the base station).

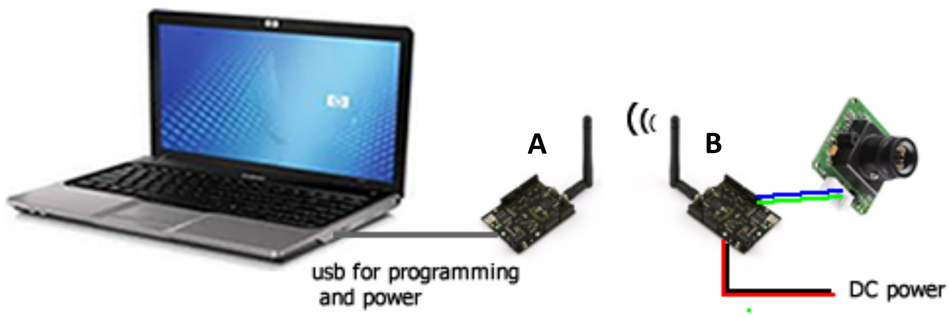

Figure 2: Wirelessly paired microcontrollers with a camera module attached.

Communication with the camera is established by sending commands in hexadecimal. Figure 3 is a flow chart that shows how the image data will be processed. To start image capture, board A will send "`0x5600360100`" to board B and the camera will respond will with "`0x7600360000`" to signal that the image capture has begun. After the image is captured the size of the JPEG image is requested so that it can be saved as a file. "`0xFFD8`" indicates the beginning of the JPEG file and "`0xFFD9`" represents the end of the file which stops the data reading loop. Figure 4 shows a Zigduino sample code written on the Arduino IDE which is used to control the LinkSprite JPEG camera.

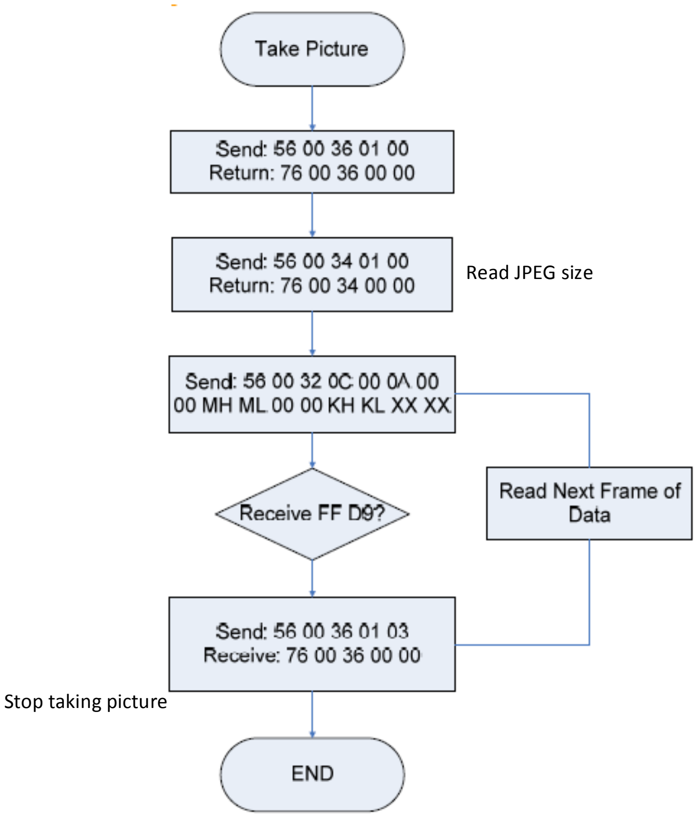

Figure 3: Flow chart of image acquisition. [8]

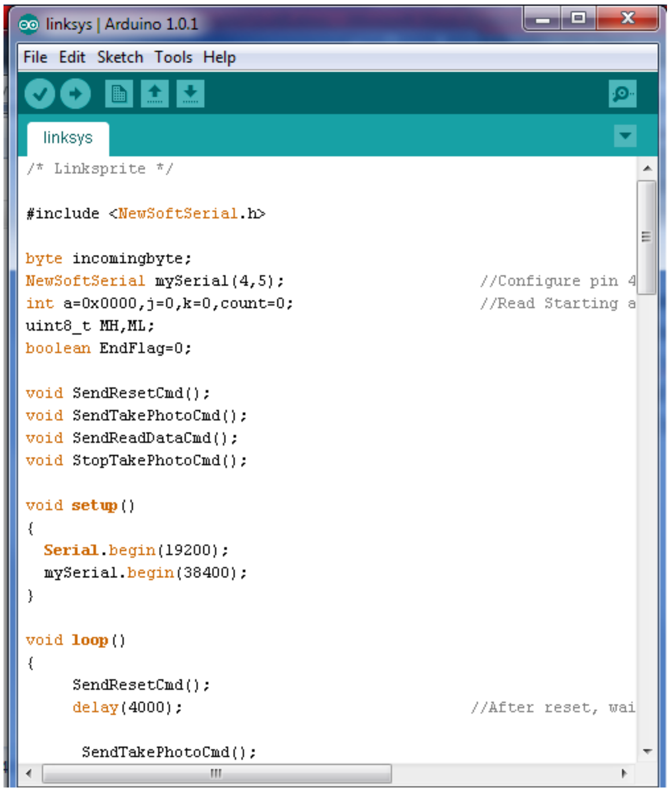

Figure 4: Sample code in Arduino IDE.

2.1.2 Image Vibration Reduction

The process of overlaying a series of images captured from different viewpoints by a vision sensor is known as image registration. The images captured from a camera in vibration are transformed geometrically by rotation, translation, skewing or scaling. Feature based and intensity based registration are two basic methods for image registration. In these methods Hough transform and phase correlation can be used to find translational and rotational differences between image sequences [9]. These techniques basically identify lines within an image space by superimposition with the Hough space (figure 5), and therefore can be extended to detect the position of objects in the image. The Hough feature extraction technique is represented by the equation of a line,

$$r(\theta) = x_0 \cdot cos\theta + y_0 \sin\theta \qquad - ①$$

Where r is the distance from the origin to the line and θ is the angle.

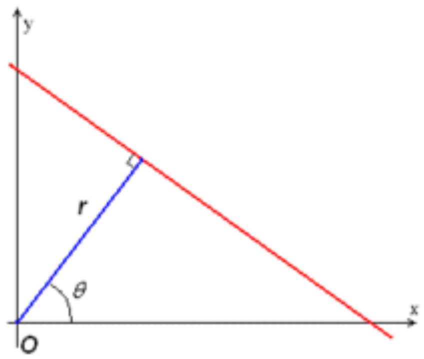

Figure 5: Polar coordinate of Hough transform. [11]

After the features of the images are retrieved, the geometrical variation can then be used in a feedback system to control the actuators of the flying UAV. Furthermore, the influence of vibration can be classified into two aspects as described in [10], which are:

1. Single frequency vibrations; and
2. Composite frequency vibrations.

In composite frequency vibrations, the device is subjected to both low and high frequency vibrations. The vibration can be expressed as a sinusoid s(t).

$$s(t) = Asin(2\pi ft + \varphi)$$

Where A is the amplitude of the vibration, f is its frequency, and φ is the phase. Therefore the designed system's aim is to extract the vibrational direction information from images/video feeds that the vision sensor produces (Figure 6). x(t) and y(t) can be derived for any angle θ by the equations:

$$\begin{cases} x(t) = Asin(2\pi ft + \varphi)cos\theta \\ y(t) = Asin(2\pi ft + \varphi)sin\theta \end{cases}$$

Figure 6: Geometrical transformation using straight line features from image.

Other related studies have tried to simulate and analyse vibration blur [10], high-frame rate target tracking [12], full spectrum vibration suppression [13], and vibration suppression in medical imaging systems with zero vibration control [14]. In [15], the feasibility of vibration suppression of a flexible robot arm using image features of unknown objects was carried out. The vibration reduction can be implemented using MATLAB as shown in the potential algorithm below.

```
Algorithm Vibration reduction
  Input: A sequence of images captured by vision sensors of the UAV.
  Output: Degree of rotation or translation
//UAV should be moved in opposite direction to negate vibration effects
For each image captured do
Linear feature generation from objects in the scene using Hough transform
   If(Θ>threshold) then
   Orientation determination
   extraction of information for flight feedback control
   end if
return de-vibration parameter //in polar or Cartesian coordinates
end for
```

2.1.3 Image Glare Reduction

There are numbers of approaches to reduce glare in images by high dynamic range imaging, but these techniques are not easily applicable to UAVs in flight because the images contain moving objects. The variety of colours can be comprehensively described by three numerical coordinates in the colour space. These standards were adopted by Commission Internationale de L'Éclairage (CIE) in 1931 and colours can be represented by the "CIE XYZ" or RGB specification [16]. In order to correct the white balance in a glared image, each of the individual elements of the colour space as shown in the equation below should be adjusted appropriately.

$$X, Y, Z = \int_{\lambda} \varphi(\lambda) \cdot x, y, z(\lambda) d\lambda$$

Where x, y, z are the sensitivities with only positive real values and $\varphi(\lambda)$is the spectral power distribution.

Another glare removal technique involves the use of a CMOS camera to pinpoint multiple sources of sun reflection in an image which will trigger selected pixels on an overlaying liquid crystal display (LCD) to dim the intensity of the glare sources in real-time [17]. Also, a real-time adaptive dynamic range camera with a liquid crystal light modulator and a charge-coupled device (CCD) detector produced a good result in [21], but the heavy hardware makes it inapplicable to the miniature drone's payload capacity. Other similar studies have successfully detected and removed image glare caused by other environmental factors that degrade image quality such as water droplets [18]. From these studies it can be seen that the main goal is to balance areas in an image that have high luminance. The glare reduction process is summarized in figure 7 below. The dark spots show areas of glare in the original image.

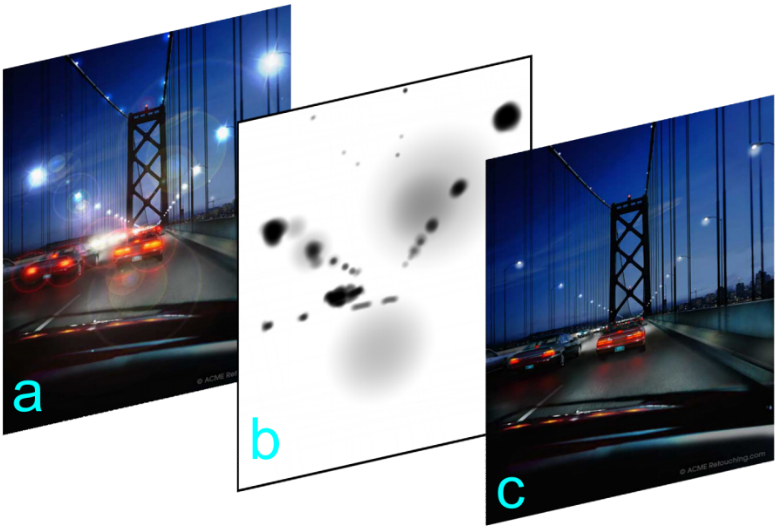

Figure 7: Summary of glare reduction process.
a) Original image [22] b) High luminance mask c) Corrected image

Luminance can be described as the brightness of light reflection on a surface [19]. The mathematical expression of luminance is:

$$L_v = \frac{d^2\Phi_v}{dAd\Omega cos\theta}$$

Where L_v is luminance (candela/ sq. metre), Φ_v is luminous flux, θ is the angular difference between the specified direction and the surface normal, A is the surface area, and Ω is the solid angle. [19]

This project will survey the hypothesis of correcting an image by applying a grid to block out areas with glare effects by using MATLAB software to manipulate each pixel in the image without the use of additional hardware on the CMOS camera module. The reflection reduction can be implemented using MATLAB as shown in the potential algorithm below.

```
Algorithm Reflection reduction
  Input: An image with glare effect
  Output: Corrected image
1: Determine the dynamic range of image
```

```
create a matrix with similar dimension to image
If(image[i,j]> luminance threshold) then
increase the value of matrix cell and some neighbouring cells.
end if
correct image according to the luminance matrix
return corrected image
```

2.2 Design of Evaluation

Firstly, the data collected from the detected image vibration will be plotted and analysed for information that will be necessary for image reconstruction or used as a feedback control to improve flight stability of the drones. A potential method of evaluating the system will be to oscillate the wireless vision sensor node at a constant frequency and use the data acquired from the images to find the correlation.

Secondly, the evaluation of the reflection/glare reduction will be carried out in MATLAB by comparing how accurately image features can be identified on original image versus the image with balanced lighting.

Further error analysis for computationally modified images will be researched and possible used to evaluate the designed system.

3. Review of Project Plan

The individual tasks and milestones in the project timeline Gantt chart have been completed up to date (i.e. red line in Appendix A: chart). The chart in appendix A shows that most of the work has been completed in the first semester, except for hardware setup and prototyping which needs further troubleshooting. The chart in appendix B shows the remaining part of the project which will be completed in the following semester. The next phase of the project includes implementation of the proposed hypothesis, obtaining of data, and data analysis. The chart from the project specification was updated because the date for implementation is meant to be before the date for obtaining of data. The next milestone will be the project dissertation and presentation.

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Appendix A: Gantt chart of Project timeline showing the progress made in the first semester.

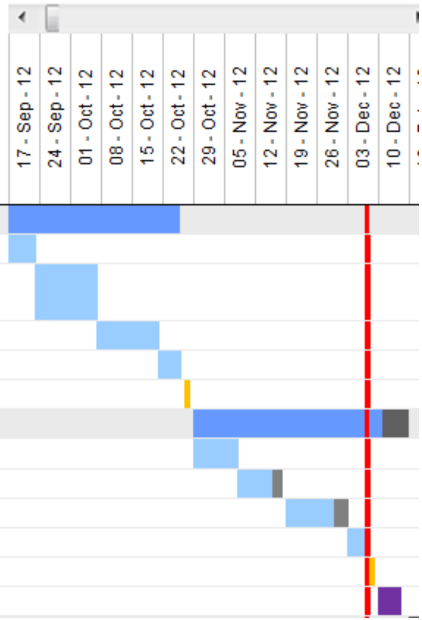
Xi'an Jiaotong Liverpool University, CSSE Final Year Project Timeline

Today's Date: 07/12/2012 Friday
(vertical red line)

Project Lead: David AFOLABI
Start Date: 03/09/12 Monday

First Day of Week (Mon=2): 2

WBS	Tasks	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	Semester 1 First-half	9/3/12	10/25/12	53	100%	39	53	0
1.1	Literature Review	9/3/12	9/22/12	20	100%	15	20	0
1.2	Brainstorming & Hardware Survey	9/23/12	10/6/12	14	100%	10	14	0
1.3	Project Plan & Risk Analysis	10/7/12	10/20/12	14	100%	10	14	0
1.4	Project Specification	10/21/12	10/25/12	5	100%	4	5	0
	*Deliverable Deadline		10/26/12	Submitted				
2	Semester 1 Second-half	10/29/12	12/17/12	50	88%	36	43	7
2.1	Review	10/29/12	11/7/12	10	100%	8	10	0
2.2	Hardware Setup	11/8/12	11/17/12	10	80%	7	8	2
2.3	Prototyping / Evaluation	11/19/12	12/2/12	14	80%	10	11	3
2.4	Design Document	12/3/12	12/7/12	5	100%	5	5	0
	*Deliverable Deadline		12/7/12					
2.5	Presentation	12/10/12	12/17/12					



Appendix B: Gantt chart of Project timeline for the remaining phase in the second semester.

Xi'an Jiaotong Liverpool University, CSSE Final Year Project Timeline

Today's Date: 07/12/2012 Friday
(vertical red line)

Project Lead: David AFOLABI
Start Date: 03/09/12 Monday

First Day of Week (Mon=2): 2

WBS	Tasks	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
3	Semester 2 First-half	2/15/13	4/23/13	68	0%	48	0	68
3.1	Implementation of Proposed Solution	2/15/13	2/28/13	14	0%	10	0	14
3.2	Obtaining Data	3/1/13	3/20/13	20	0%	14	0	20
3.3	Experiment	3/21/13	4/9/13	20	0%	14	0	20
3.4	Data Analysis	4/10/13	4/23/13	14	0%	10	0	14
4	Semester 2 Second-half	4/23/13	5/26/13	34	0%	24	0	34
4.1	Evaluation & Summary	4/23/13	5/6/13	14	0%	10	0	14
4.2	Project Dissertation	5/7/13	5/24/13	18	0%	14	0	18
	*Deliverable Deadline		5/24/13					
4.3	Presentation	5/27/13	5/26/13