Design & Development of a Smart Ball Based Surveillance System using AI (BKV-1)

Technical and Financial Proposal

Proposal Reference
0986/02/DRD/NUST/02

Defence R&D Directorate
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Overview

Ser	Particular	
a.	Name of PI (1)	Dr. Muhammad Jawad Khan
b.	Name of PI (2)	Dr. Muhammad Usman Bhutta
c.	Institute	National University of Sciences and Technology
d.	Total Project Cost	4.96M
e.	Duration	12 Months
f.	Funding Agency	DRD Dte
g.	Objectives	a. Literature / market review b. Interfacing of instrumentation c. Emulation of measurements d. Software Design and Integration e. Automated testing and calibration f. Detailed Documentation
h.	Deliverables	● Calibration system ● GUI based Operating Software (windows) ● Detailed documentation ● Training and handover ● Technical support

Table of Contents

1. Background 5

1.1 Introduction 5

1.2 Objectives 5

1.3 Methodology 6

1.4 Testing 8

1.5 Specifications 9

1.6 Risk Analysis 9

2. HR Requirements 11

3. Instrumentation Requirements 11

4. Project Timelines 12

5. Deliverables 13

6. Financial Proposal 13

7. Contractual Matters 14

List of Figures

Figure 1: Project Methodology 6

Figure 2: Image Stitching 7

Figure 3: Initial Prototype of the System along with the Multi-Camera Streaming 7

Figure 4: Ball Cameras sending data to remote base station 8

List of Tables

Table 1: Project Specifications 9

Table 2: HR Requirements 11

Table 3a : Instrumentation Requirements 11

Table 3b : Components Requirements 12

Table 4: Project Timelines 12

Table 5 : Financial Proposal 13

1. Background

1.1 Introduction

Intelligence operations play a vital role in the national security of a country. Law enforcement forces rely on the intelligence reports to conduct operations for preventing terrorist activities. It is important that intelligence reports be accurate and timely. One of the main challenges faced by the law enforcement forces during Surveillance and Reconnaissance missions are the lack of infrastructure for communication and monitoring. Mostly these operations were conducted in remote areas, with no such facilities. Recognizing this need for law enforcement forces and also to address this challenge we proposed a wireless based multi camera imagery device for real-time capturing and transmission of imagery data to a nearly deployed Ad-hoc mobile base station.

The proposed solution consists of a software and hardware pipeline for a throwable ball shaped imaging device, that would be able to capture the high resolution imagery data using multiple RGB cameras and transmit that data to a base-station. At base-station, the artificial intelligence algorithm will be applied to the imagery data for detecting the person of interest. Using throwable imagery devices for surveillance application will allow law enforcement forces to effectively locate, observe and engage a range of targets in their intelligence, surveillance and reconnaissance (ISR) missions.

1.2 Objectives

The objectives of the project are as follows:

a. To develop a robotic ball with vision sensors for surveillance and reconnaissance missions.
b. To develop a web based user interface in a base station to view the acquired footage
c. Real time capture and transmitting the image data to the base station

1.3 Methodology

The first version of the project is being proposed in this submission. This project *'Design & Development of a Smart Ball Based Surveillance System using AI (BKV-1)'* is being proposed keeping in view the complete overall requirements sent by the Def R&D Dte NUST with the flexibility to be upgraded to incorporate the complete requirements in future versions.

A sphere is "the set of all points in three-dimensional space lying the same distance radially from the center. In terms of imaging devices, a spherical structure can freely rotate in any direction where all positions are stable. The shape of a sphere provides complete symmetry and a soft, safe, and friendly look without any sharp corners or protrusions, which is advantageous when an imaging device is dealing with small spaces. The spherical ball that will be used in this project would be almost the size of a football (around 23 cm in diameter) that would be able to take photos from up to 16 cameras which would be stitched together during processing enabling complete field of view of the horizontal space of exposure. The cameras will be used to take high-resolution images that will be transmitted to the base station where AI algorithms would be used to detect humans and concerned persons appearing in an image. The trigger to control the image acquisition would also be remote-controlled through the base station allowing pictures to be taken without requiring any physical access to the ball. The complete methodology has been schematically presented in figure 1 below.

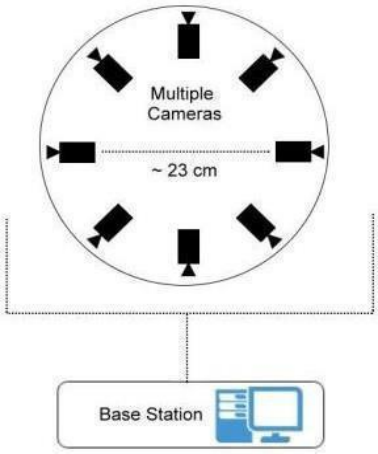

Figure 1: Project Methodology

Moreover, setting of exposure time, ISO, white balance would also be performed remotely by the base station. The bespoke design would allow smooth integration of the cameras, batteries, data acquisition system, image processing unit and AI algorithms to allow the most optimized performance within the given limited space with minimum battery consumption. The solution being proposed will use a high processing on-board computer that will be interfaced with multiple image capturing cameras coupled with a multiplexer which will perform on-board processing and transmission of the image to the stakeholder. Image Stitching as shown in figure 2 is a technique used to solve the FOV (Field of View) Limitation of Image capturing sensors, as the cameras have a specific field of view and can cover the limited area. This technique will be applicable to resolve the issue by detecting similar key points in multiple images using feature extraction algorithms, and match the key points in images and then computer vision algorithms will be used to estimate the homography matrix on the basis of previously computed matched feature vectors. The homographic matrix will then be used to perform the transformation.

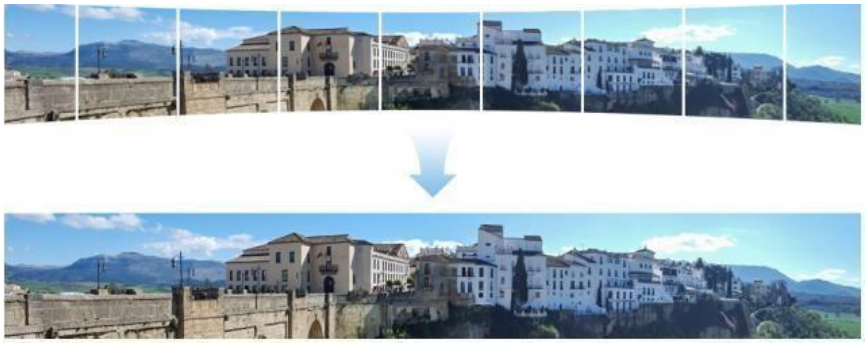

Figure 2: Image Stitching

The proof-of-concept of the complete project has already been performed by the team by developing and testing an initial prototype of the project.

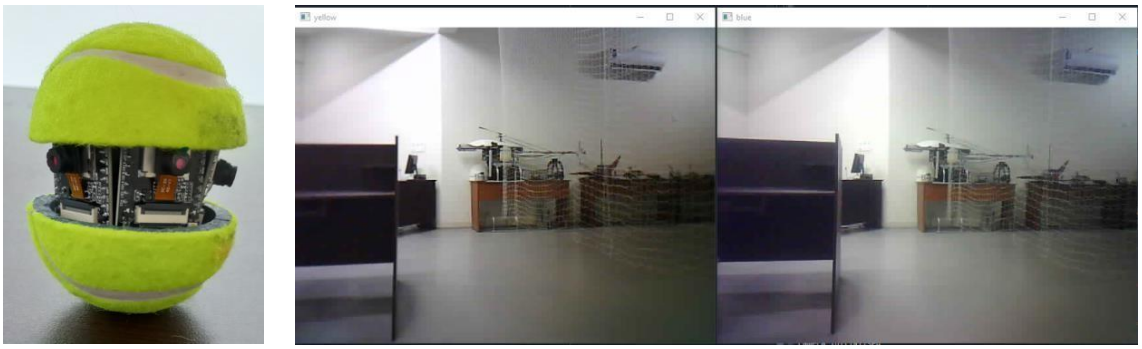

Figure 3: Initial Prototype of the System along with the Multi-Camera Streaming

The developed prototype has been pictorially presented in figure 3. The ball would be able to send the image data to the base station through Wi-Fi as shown in Figure 4. There would be a user interface in the form of a computer based application which would be accessible by Microsoft Windows connected to the network. The data of the base station will be accessible on mobile phones (Android and iOS) from a web browser. A dedicated application can be developed in future versions.

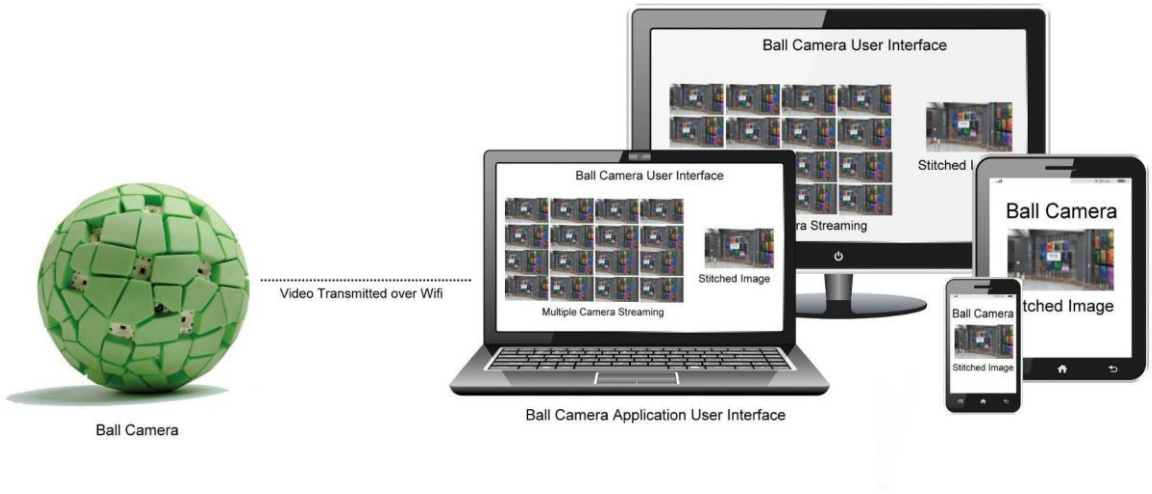

Figure 4: Ball Cameras sending data to remote base station

To avoid blurriness, the images should be taken when the ball is motionless. If the ball is moving when the picture is taken, the images may come out to be blurry. The images will be transmitted to the base station where different analytics will be performed on the image.

1.4 Testing

The proposed device will be tested according to various test cases to examine the build quality, durability, response in different weather and lightning conditions.

1.5 Specifications

Table 1: Project Specifications

#	Features	Comments
1.	Number of Cameras	Up to 16 cameras.
2.	Size of the Ball	Approximately 25cm diameter.
3.	Battery Capacity	Approximately 7000mAh - 15000mAh Lithium battery.
4.	Charging Time	Approximately 1.5 hours to 2 hours.
5.	Communication Protocol	Imagery data will be transmitted to the base station via WiFi (IEEE 802.11)
6.	User Interface	Multiple devices and screen responsive computer based application will be developed.
7.	FPS (Frames Per Second) of the camera	10 – 16 fps, in ideal conditions, depending on the received signal strength intensity.
8.	Shock Proof Properties	The ball device will be shockproof upto a certain height and depending on material it falls on.
9.	Accelerometer	The Ball Camera will be equipped with a Triple Axis Compass Accelerometer Module GY-61 ADXL335, which will be used to check the zero speed, either the ball is in motion or in a stationary position.

1.6 Risk Analysis

Risk Analysis is a proven way of identifying and assessing factors that could negatively affect the success of a business or project. The ball would be tested through various tests in order to find the most suitable factors, which will create a long-lasting product. The ball should be handled with care to make it function in an expected manner. Some of the risks, which the robotic ball can be affected by, are:

1.6.1 High Impact Shock

A high impact shock, like throwing it to the ground, or a high load object being thrown at the ball may damage it beyond repair.

1.6.2 High Magnetic fields

A magnetic field of high intensity may damage the ball's circuitry which may require repairs.

1.6.3 High Voltage Charge

The ball should be charged with the recommended voltage and with the recommended charger option. A high voltage may damage the internal circuitry of the ball.

1.7 Benefits of the project

This project will be beneficial in the national interest and facilitate the law-enforcement forces in their intelligence, surveillance, and reconnaissance (ISR) missions to identify, prevent and eliminate terrorist activities.

2. HR Requirements

The following 3 team members will be required to work under supervision of PI:

Table 2: HR Requirements

S No	Job Title	Role
1.	Principal Investigator - 1	Responsible for all the tasks regarding Embedded Systems, AI and Hardware Software Interfacing.
2.	Principal Investigator - 2	Responsible for Designing Ball Camera Structure.
3.	Embedded System Engineer	Responsible for Hardware Interfacing of Ball Camera
4	Software Engineer	Responsible for UI Design and Firmware Programming

3. Instrumentation Requirements

Table 3a : Instrumentation Requirements

S No	PME	Quantity
1.	Digital Multimeter	2
2.	Power Supply	2
3.	Soldering Kits	2
4.	Screw Drivers	2
5.	Glue Gun	2
6.	Scissors / Cutters	2

Table 3b: Components Requirements

S No	Equipment	Quantity
1.	3D Printer / Filament	1
2.	Work Stations	1
3.	Single Board Computers	3
4.	Field Laptop (Rugged)	1
5.	Vision Sensors	30
6.	Electronics Equipment (Sensors, Voltage Regulators, Batteries)	30
7.	Networking Equipment (Routers, Switches, Multiplexers)	4

4. Project Timelines

Table 4: Project Timelines

Tasks	Timeline (In months)											
	1	2	3	4	5	6	7	8	9	10	11	12
Detail design feasibility analysis & simulations	■	■										
Procurement of components and consumables		■	■	■	■							
Hardware Interfacing & Emulation			■	■	■	■						
Software Design and Integration with hardware				■	■	■	■					
Testing and calibration							■	■	■	■	■	
Detailed Documentation, Training, and Handover											■	■

5. Deliverables

a. The complete ball device with all accessories attached.

b. The base station with user friendly GUI.

c. A computer based application to access ball streams on the local network.

6. Financial Proposal

SMME-NUST is pleased to offer following charges against the project titled: Design & Development of a Smart Ball Based Surveillance System using AI (BKV-1).

Table 5 : Financial Proposal

Budget Element	Amount (Rs)
Personnel Costs	
PI, CO-PI, Team Members & Technical Staff	2,520,000
Equipment	
Total Equipment Cost	2,057,000
Consumables & Services	
Electrical & Mechanical Consumables	5,000
Travel Cost	4,000
Sub Total Budget (Direct Cost)	**4,586,000**
Overheads (Indirect Cost)	374,000
Total Budget	**4,960,000**
Note:- For further clarity HEC-NRPU budget template is to be consulted: HEC budget Template	

7. Contractual Matters

a. Contractual obligations under the project (Concerning third party)
b. Ownership of Intellectual Property Rights
c. Competent Authority of the PI's organization

Name: (1) Dr. Muhammad Jawad Khan (2) Dr. Muhammad Usman Bhutta

Designation: (1) Assistant Professor (2) Assistant professor

Email: (1) jawad.khan@smme.nust.edu.pk (2) usmanbhutta@smme.nust.edu.pk

Date: 25/07/2022

(Signature & Stamp of Commandant / Head of Institution)

Dr. Javaid Iqbal
Principal & Dean
School of Mechanical &
Manufacturing Engineering
(SMME) NUST, Islamabad

Surety Certificate

Title of the Project: **Design & Development of a Smart Ball Based Surveillance System using AI (BKV-1)**

PI:-1: Dr. Muhammad Jawad Khan **PI-2: Dr. Muhammad Usman Bhutta**

Funding Agency: DRD Fund-NUST **Amount: 4.96 Million**

It is certified that the proposal has been scrutinized for following: -

(a) Targets set by the PI are attainable / reasonable.

(b) Track record of PI is sound and qualification adequate.

(c) The PI has shown commitment to complete the project if awarded.

(d) He has been informed that he will be responsible to transfer the project in accordance with rules / regulations in case he leaves the institution or desires to proceed on course / long leave.

Signature of PI-1 **Signature of PI-2** **Head of Institution**