



**'The guidelines of parameters in the  
implementation of local monocular vision system  
for robot soccer using the mirosot platform**

by

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“The journey of our lives is not just about the destinations we have reached. Our wisdom, education and personal growth come from the people we meet, the paths we choose to follow and the lessons we have learned along the way.”

- Unknown

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## TABLE OF CONTENTS

	<b>PAGE</b>
DECLARATION OF THESIS	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iv
LIST OF FIGURES	x
LIST OF TABLES	xii
LIST OF ABBREVIATION	xiv
LIST OF SYMBOLS	xvii
ABSTRACT	xviii
ABSTRAK	xix
CHAPTER 1: INTRODUCTION	
1.1 Research Background	1
1.2 Motivation	3
1.3 Problem Statement	5
1.4 Objective of Thesis	6
1.5 Organization of the Thesis	10
CHAPTER 2 : LITERATURE REVIEW	
2.1 Introduction	11

2.2	Micro Robot Soccer Tournament (MiroSot)	12
2.2.1	Functionality of MiroSot	13
2.2.2	MiroSot Soccer Robots	15
2.2.3	Discussion	16
2.3	Types of Robot Soccer Vision Setup	17
2.3.1	Global Vision – center of field	17
2.3.2	Global Vision – side of field	20
2.3.3	Local Vision – Omnidirectional	20
2.3.4	Local Vision – Stereo	22
2.3.5	Local Vision – Monocular	23
2.3.6.	Discussion	26
2.4	Monocular Vision in Other Application	26
2.4.1	Surveillance and Security	27
2.4.2	Industry and Manufacturing	27
2.4.3	Vehicle Guidance	29
2.4.4	Mobile Robots	30
2.4.5	Discussion	31
2.5	Parameters in Monocular Vision	32
2.5.1	Frame Rate	33
2.5.2	Frame Size	36
2.5.3	Color Models	36
2.5.4	Object Identification	37
2.5.5	Distance Estimation	38
2.5.6	Discussion	40
2.6	Summary	41

## CHAPTER 3 : RESEARCH METHODOLOGY

3.1	Introduction	43
3.2	Hardware Framework	43
3.2.1	Video Capturing Device	44
3.2.1.1	Technical Specification	44
3.2.1.2	Camera-to-Receiver: Wireless Technology	45
3.2.1.3	Calibration Settings	46
3.2.1.4	Video Capturing Device Chosen	47
3.2.2	Soccer Robot	52
3.2.2.1	Physical Specification	52
3.2.2.2	Robot-to-Computer: Wireless Technology	53
3.2.2.3	Soccer Robots Chosen	53
3.2.3	Processing Unit	55
3.2.3.1	Technical Specification	55
3.2.3.2	Connectivity Requirements	56
3.2.3.3	Processing Unit Chosen	56
3.3	Software Architecture	58
3.3.1	Vision System	61
3.3.1.1	VideoCap	62
3.3.1.2	ColorSeg	65
3.3.1.3	ShapeDetect	67
3.3.1.4	DimCompute	69
3.3.1.5	Occlusion Handling	70
3.3.1.6	Vision2AI Communication	71
3.3.1.7	Sample Program Execution	72

3.3.2	Artificial Intelligence System	75
3.3.2.1	AI2Vision Communication	76
3.3.2.2	Distance Estimation	76
3.3.2.3	Test Pattern Movements	85
3.3.2.4	AI2Comm Communication	87
3.3.2.5	Sample Program Execution	88
3.3.3	Communication System	89
3.3.3.1	Comm2AI Communication	89
3.3.3.2	Computer-to-Robot Communication	90
3.3.3.3	Sample Program Execution	91
3.4	System Testing	93
3.4.1	Experiment Setup	94
3.4.2	Playing Field Requirement	95
3.4.3	Display Format Testing	96
3.4.4	Color Model Testing	97
3.4.5	Real-Time Vision	98
3.4.6	Experiments	98
3.4.6.1	Experiment 1: Full Video versus Split Video –Displayed	99
3.4.6.2	Experiment 2: Full Video versus Split Video – No Displayed	99
3.4.6.3	Experiment 3: RGB – Distance Estimation	100
3.4.6.4	Experiment 4: HSV – Full Video and Split Video	101
3.4.6.5	Experiment 5: YUV – Full Video	102

3.5	Summary	102
CHAPTER 4: RESULTS AND DISCUSSION		
4.1	Introduction	104
4.2	Experiments	104
4.2.1	Experiment 1: Full Video versus Split Video – Displayed	105
4.2.1.1	Results	105
4.2.1.2	Analysis of Results for Full Video	107
4.2.1.3	Problems with Full Video	109
4.2.1.4	Analysis of Results for Split Video	112
4.2.2	Experiment 2: Full Video versus Split Video – Not Displayed	115
4.2.2.1	Results	115
4.2.2.2	Analysis of Results for Full Video versus Split Video – Not Displayed	116
4.2.3	Experiment 3: RGB – Distance Estimation	118
4.2.3.1	Results	119
4.2.3.2	Error Analysis	122
4.2.4	Experiment 4: HSV Color Model	123
4.2.4.1	Results	124
4.2.4.2	Error Analysis	125
4.2.5	Experiment 5: YUV Color Model	126
4.2.5.1	Results	126
4.2.5.2	Error Analysis	127
4.3	Comparison of Color Models	128

4.4	Challenges and Assumptions	129
4.4.1	3D Object Non-Uniform Illumination	129
4.4.2	Camera – Automatic Gain	132
4.4.3	Camera – Lens Hood	132
4.4.4	Camera – CMOS Type Sensor	133
4.4.5	Robot Speed	135
4.4.6	Discussion	137
4.5	Objectives Summary	139
4.6	Summary	140
<b>CHAPTER 5 : CONCLUSION AND RECOMMENDATIONS</b>		
5.1	Introduction	142
5.2	Summary of the chapters	142
5.3	Proposal of The Guideline of Parameter for the Implementation of Local Monocular Vision System in Robot Soccer	145
5.4	Significant of the research	147
5.5	Limitation	148
5.6	Future Recommendation	150
<b>REFERENCES</b>		152
<b>LIST OF PUBLICATIONS</b>		162

## LIST OF FIGURES

NO.		PAGE
2.1	MiroSot Systems Setup	12
2.2	MiroSot Systems Cycle	14
2.3	MiroSot Robot Soccer Movement Description	16
2.4	Playing Field (Left) without Fish-Eye Effect (Right) with Fish Eye Effect.	18
3.1	Video Capture Device consisting of one KT-2418 Wireless Receiver (Left) and C-100A Wireless Camera (Right)	49
3.2	Calibration Procedure using a Focus Calibration (Left) and a Color Calibration (Right)	51
3.3	Four Merlin Miabot PRO	54
3.4	On Board Camera Placement	55
3.5	The Processing Unit	57
3.6	General Software Architecture Design	58
3.7	Software Framework Design	60
3.8	VideoCap Software Design	63
3.9	ColorSeg Software Design	67
3.10	ShapeDetect Software Design	68
3.11	Vision System Snapshot	73
3.12	Windows Displayed During Program Execution	74
3.13	Circle Calibration Plot	78
3.14	Residual of Circle Calibration Plot	80

3.15	Large Rectangle Calibration Plot	82
3.16	Residual of Large Calibration Plot	82
3.17	Small Rectangle Calibration Plot	84
3.18	Residual of Small Rectangle Calibration Plot	84
3.19	Test Pattern Movement	85
3.20	AI System Snapshot	88
3.21	Bluetooth Setup	92
3.22	Communication System Snapshot	93
3.23	Experiment Setup	95
3.24	Processing Display Formats	97
4.1	Original Unprocessed Video from Wireless Receiver	107
4.2	Full Video - Processed Using RGB Segmentation (Without Borders)	108
4.3	Object Detection Overlap between Camera3 and Camera4	109
4.4	Full Video - Processed Using RGB Segmentation (With Borders)	110
4.5	Don't-Care Region	111
4.6	Object Detection Not Overlapped between Camera3 and Camera4	112
4.7	Split Video - Processed Using RGB Segmentation	113
4.8	Calibration Method Results	121
4.9	Ball's non uniform illumination	130
4.10	Ball Object Detection	131
4.11	Lens Hood	133
4.12	Effect of Rolling Shutter	134

## LIST OF TABLES

NO.		PAGE
2.1	MiroSot Movement of Motor	15
2.2	Global Vision Processing Parameters	18
2.3	Robot Soccer Using Monocular Vision Published Works	24
3.1	Comparison of Wireless Camera Types	48
3.2	Calibration Setting on Camera Side and Receiver Side	50
3.3	Object and its color and dimensions	69
3.4	Circle Calibration Data	77
3.5	Circle Trend Line Comparison	79
3.5	Large Rectangle Calibration Data	80
3.6	Large Rectangle Trend Line Comparison	81
3.7	Small Rectangle Calibration Data	83
3.8	Small Rectangle Trend Line Comparison	83
3.9	Test Movement for Robots	87
3.10	Real-time Video Processing	98
3.11	RGB Color segmentation values	100
4.1	Results between Full Video and Split Video	106
4.2	Statistical Data for Full Video and Split Video	114
4.3	Results between Full Video and Split Video – Not Displayed	115
4.4	Statistical Data for Full Video and Split Video – Not Displayed	116
4.5	Statistical Data for Full Video and Split Video	118
4.6	Computed versus Actual Distance for Calibration Method	119
4.7	(Left) Result if the H parameter changes by $\pm 1$ px,	123

(Right) Results if W parameter changes by  $\pm 5$ px.

4.8	Results between Full Video and Split Video for HSV	124
4.9	Comparison of Statistical Data between Full Video and Split Video for HSV	125
4.10	Results between Full Video and Split Video for YUV	126
4.11	Statistical data between Full Video and Split Video for YUV	127
4.12	Comparison between RGB, HSV and YUV	128
4.13	Dimension Computation at Variable Speed	137

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## LIST OF ABBREVIATIONS

3D	-	Three Dimension
AI	-	Artificial Intelligence
AI2Comm	-	Communication subprogram from the Artificial Intelligence System to the Communication System
AI2Vision	-	Communication subprogram from the Artificial Intelligence System to the Vision System
AndroSoT	-	Android Robot Soccer Tournament
ANPR	-	Automated Number Plate Recognition
avgFPS	-	Average Frame Rate
CCD	-	Charge Coupled Device
CCTV	-	Close Circuit Television
CMOS	-	Complementary Metal Oxide Semiconductor
colorID	-	Color Identification
Comm	-	Communication
Comm2AI	-	Communication subprogram from the Communication System to the Artificial Intelligence System
coord_x	-	Coordinate of X-axis
coord_y	-	Coordinate of Y-axis
CRT	-	Cathode Ray Tube
D	-	Diameter
DARPA	-	Defense Advanced Research Projects Agency
DARwIn-OP	-	Dynamic Anthropomorphic Robot with Intelligence-Open Platform
FIRA	-	Federal International Robot Soccer Association

H	-	Height
HSL	-	Hue-Saturation-Luminance
HSV	-	Hue-Saturation-Value
HuroSoT	-	Humanoid Robot Soccer Tournament
IP	-	Internet Protocol
ISM	-	Industrial, Scientific and Medical Radio Bands
KAIST	-	Korea Advanced Institute of Science and Technology
L	-	Length
maxFPS	-	Maximum Frame Rate
minFPS	-	Minimum Frame Rate
MiroSoT	-	Micro Robot Soccer Tournament
OCR	-	Optical Character Recognition
OpenCV	-	Open Computer Vision
RAM	-	Random Access Memory
RGB	-	Red-Green-Blue
RoboCup	-	Robot Soccer World Cup
RoboSoT	-	Robot Soccer Tournament
robotID	-	Robot Identification
SDK	-	Software Development Kit
shapeID	-	Shape Identification
SLAM	-	Self-Localization and Mapping
UHF	-	Ultra High Frequency
USB	-	Universal Serial Bus
UWB	-	Ultra Wide Band
VDU	-	Visual Display Unit

Velocity_left	-	Left Wheel Velocity
Velocity_right	-	Right Wheel Velocity
VHF	-	Very High Frequency
Vision2AI	-	Communication subprogram from the Vision System to the Artificial Intelligence System
vl	-	Velocity of Left Wheel
vr	-	Velocity of Right Wheel
VSP	-	Virtual Serial Port
W	-	Width
WiFi	-	Wireless International Technology
YUV	-	One luminance and two chrominance

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## LIST OF SYMBOLS

Avg	-	Average
bps	-	Bits per second
cm	-	Centimeters
fps	-	Frames per second
g	-	Grams
GB	-	Giga Byte
GHz	-	Giga Hertz
Hz	-	Hertz
lx	-	Lux
m/s	-	Meters per second
MB	-	Mega Byte
MHz	-	Mega Hertz
mm	-	Millimeters
mm/ms	-	Millimeters per millisecond
mW	-	Milliwatts
px	-	Pixel
V	-	Volts

## The Guidelines of Parameters in the Implementation of Local Monocular Vision System for Robot Soccer Using the MiroSoT Platform

### ABSTRACT

The conception of robot that plays soccer was a major step in autonomous multi agent system, many agents that work together to achieve a common goal. This research field was promoted with the introduction of two international events, the Federal International Robot Soccer Association (FIRA) and Robot Soccer Cup (RoboCup). Similar to the real human game of soccer, the player rely the most on his vision as the source of information about his environment and this duplicated into robot soccer, which allows for the use of cameras as the single sensor. This research will experiment five concepts to determine the guidelines needed in the implementation of local monocular vision system. The experiment are (a) the minimum frame rate for the establishment real-time vision, (b) various color model and segmentation techniques and its efficiency in terms of frame rate, (c) the type of object detected (d) The processing of the video as a complete video frame – full video, separated video for each camera – split video and (e) The influence of displaying the video or not displaying the video, during gameplay, on the frame rate. Based on the findings, the guideline of parameter was established are the minimum frame rate of 16 frames per second (fps). The experimented color models were RGB, HSV and YUV in which RGB showed a mean value of 21.38fps, HSV with a mean value of 16.00fps and YUV with a mean value of 15.60fps. RGB will be the color model of choice as it achieves the concept of real-time video. The objects to be detected are of basic geometry shapes, namely circle, small rectangle and large rectangle, which are currently employed in other robot soccer leagues. In terms of distance estimation, the calibration method proves worthwhile even though it give erroneous result when the object being detect is close range or long range. The way to solve this situation is to use these ranges by creating certain strategies such as near range for defense or kicking. Another issue tackled effects to display the real-time video or hiding (not displaying) the video. The result showed that by not displaying the video the frame rate increases by as much as 3% or an increase of about 0.8fps in average. Being the only sensor applied, the video processing that is required has to have a minimal impact in terms of processing time, which will result in the increase in frame rate. Based on the findings of these experiments, a guideline of parameters can be established in the implementation of local monocular vision system, which consist of multiple wireless camera system, processing the RGB or the raw video format coming from the camera, using the full video mode when displaying an processing, lastly to provide an option the display or not display the video hence increasing the frame rate when not needed to debug. Calibration method distance estimation can be utilized but four ranges should be define and strategies set for these ranges.

## Penetapan Parameter dalam Pelaksanaan Sistem Visi Monokular Tempatan Untuk Bola Sepak Robot dengan Menggunakan platform MiroSoT

### ABSTRAK

Konsep robot yang memainkan bola sepak merupakan langkah utama dalam autonomi sistem ejen pelbagai, banyak ejen-ejen yang bekerja bersama-sama untuk mencapai satu matlamat. Bidang penyelidikan ini telah dimajukan dengan pengenalan dua acara antarabangsa, Federal International Robot Soccer Association (FIRA) and Robot Soccer Cup (RoboCup). Sama dengan permainan bola sepak yang dimainkan oleh manusia, pemain bergantung sepenuhnya kepada deria penglihatannya sebagai sumber maklumat tentang alam sekitar dan ini dapat diulang ke dalam bola sepak robot, yang hanya membenarkan penggunaan kameras sebagai sensor tunggal. Kajian ini akan menjalankan lima eksperimen untuk menentukan garis panduan yang diperlukan dalam pelaksanaan sistem penglihatan monokular tempatan. Eksperimen tersebut adalah (a) kadar bingkai minimum untuk visi masa nyata, (b) pelbagai warna model dan segmentasi teknik dan kecekapan dari segi kadar bingkai, (c) jenis objek yang dikesan, (d) pemprosesan video sebagai bingkai video lengkap - video penuh atau dipisahkan video bagi setiap kamera - video perpecahan dan (e) pengaruh memaparkan video atau tidak memaparkan video, semasa permainan, berdasarkan kadar bingkai. Berdasarkan kajian ini, garis panduan parameter ditubuhkan adalah kadar bingkai minimum 16 bingkai sesaat (fps). Model warna dieksperimen adalah RGB, HSV dan YUV di mana RGB menunjukkan nilai min 21.38fps, HSV dengan nilai min 16.00fps dan YUV dengan nilai min 15.60fps. RGB akan menjadi model warna pilihan kerana ia mencapai konsep video video nyata. Object yang dapat dikesan adalah bentuk geometri asas, iaitu bulatan, segi empat tepat dan segi empat tepat kecil besar, yang kini digunakan dalam liga bola sepak robot. Dari segi anggaran jarak, kaedah penentuan membuktikan kebolehpercayaan walaupun ia memberikan ralat apabila object yang dikesan adalah pada jarak dekat atau jarak jauh. Cara untuk menyelesaikan keadaan ini adalah dengan menggunakan julat ini dan mewujudkan strategi tertentu seperti strategi pertahanan pada jarak dekat atau strategi menendang. Satu lagi kesan isu ditangani untuk memaparkan video masa nyata atau bersembunyi (tidak memaparkan) video. Hasilnya menunjukkan bahawa dengan tidak memaparkan video kenaikan kadar bingkai sebanyak 3% atau peningkatan kira-kira 0.8fps dalam purata. Sebagai satu-satunya sensor digunakan, pemprosesan video yang diperlukan perlu mempunyai impak yang minimum dari segi masa pemprosesan, yang akan menyebabkan peningkatan dalam kadar bingkai. Berdasarkan dapatan eksperimen ini, satu garis panduan parameter boleh diwujudkan dalam pelaksanaan sistem penglihatan monokular tempatan, yang terdiri daripada pelbagai sistem kamera tanpa wayar, pemproses RGB iaitu format video mentah dari kamera, menggunakan mod video penuh untuk paparan dan yang akhir sekali untuk menyediakan pilihan paparan atau tidak memaparkan video seterusnya meningkatkan kadar bingkai apabila tidak diperlukan untuk debug. Penentuan kaedah jarak anggaran boleh digunakan tetapi empat julat perlu menentukan dan strategi yang ditetapkan untuk julat ini.

## CHAPTER 1

### INTRODUCTION

#### 1.1 Research Background

It began with an idea to promote multi-agent autonomous robot using the popular game of soccer as a platform, hence the birth of robot soccer. Two researchers, namely Hiroaki Kitano and Minoru Asada, had a vision that has become the goal that researchers in the field of robot soccer are working on. The goal is

“By mid-21st century, a team of fully autonomous humanoid robot soccer players shall win the soccer game; comply with the official rule of the FIFA, against the winner of the most recent World Cup.”

- Hiroaki Kitano and Minoru Asada (Hiroaki Kitano & Asada, 1998)

The idea of a group of robots playing a popular game was first mentioned by Professor Alan Mackworth, from the University of British Columbia in Canada, in a paper entitled “On Seeing Robots”. This paper was later published in the book “Computer Vision: System, Theory, and Applications” (Mackworth, 1993). From this, two groups started international competitions games based on the game of soccer, namely RoboCup and FIRA.

The history of RoboCup dates back to June 1993 when a group of researchers, including Minoru Asada, Yasuo Kuniyoshi, and Hiroaki Kitano, decided to launch a

robotic competition, tentatively named the Robot J-League, where J stood for Japan, but later renamed as the Robot World Cup Initiative, 'RoboCup' for short (Matsubara, Asada, & Kitano, 2002). The history of Federation of International Robot Soccer Association or FIRA dates back to September 1995, when Professor Kim Jong Hwan of Korea Advanced Institute of Science and Technology or KAIST, formally initiated an International Organizing Committee for Micro-Robot World Cup Soccer Tournament or MiroSoT. MiroSoT'96 was first held in KAIST, between November 9 and 12, 1996 (Chiou & Wang, 2008). Since then the MiroSoT, has been the test bed for many fields related to robotics. This tournament was participated by 23 teams by nine countries competing for the Hanminjok Cup (Kim, 1997).

The term robot soccer refers to the system which consist one or many robot that is placed in a platform. These robots, which consist of two teams, will compete with each other in a game very similar to soccer. The term soccer robots refer to a specialized or custom made autonomous robot which is a mobile robot that is used to play variants of soccer.

The league has evolved from the global vision to the local vision as per the ideas of the founding fathers. The global vision utilizes one stationary camera that is attached above the playing fields and can capture the whole playing field, its markings, the robots and ball. The image processing system for the global vision converts this information to X and Y coordinates. The local vision utilizes cameras that are mounted on the robot itself and moves with the robot. The image processing system for the local vision depends on the camera mounting orientation. There are three type of local vision, omnidirectional, stereo and monocular. The omnidirectional has cameras that are mounted facing upwards towards a convex mirror hence has a 360° field-of-view, thus image processing is the distance and angle of object and markings relative to the robot

itself. The stereo has two front facing cameras similar to human eye and does distance and angle processing based on what it can capture in its field-of view.

The leagues started with the introduction of Micro Robot Soccer Tournament (MiroSoT) and Android Robot Soccer Tournament (AndroSot) where the utilization of the global vision, to Robot Soccer Tournament (RoboSot) with omnidirectional camera mounted on-board the robot and finally, Humanoid Robot Soccer Tournament (HuroSot) with two cameras on-board the robot which provides stereo vision, like the commercially available Aldebaran Nao (Aldebaran, 2013) and the Dynamic Anthropomorphic Robot with Intelligence-Open Platform (DARwin-OP) (Robotis, 2013). The vision system evolution in robot soccer started as the global vision system and has evolved to the local vision system; and in local vision system the evolution began with Omnidirectional (single camera placed on the robot facing towards a convex mirror – used in RoboSot league) and stereo (two cameras placed side-by-side and facing the front – used in HuroSot League). The evolution poses an interesting part for research in term of vision system where the monocular vision system was not experimented, tested or utilized in any league.

## 1.2 Motivation

As mentioned above, the evolution poses an interesting part for research in the vision system utilized on Robot Soccer which is to create a guideline of parameters that supports the utilization of a single front facing camera on each robot, the guidelines for the utilization of local monocular vision system in Robot Soccer. The platform that will be used for the testing of this guideline will be the MiroSoT League Robot Soccer, due to this league being the test bed since the creation of robot soccer.

The robot soccer leagues mostly are custom made and have its development basis is from researches. The global vision provides simple and easy method of vision. Omni directional vision was also born from research with vision system. Due to the development of commercially available robots, stereo vision from robot such as the Nao and DARwIn-OP were directly used. Monocular vision has not been utilized, especially when considering the use of vision sensors as the only sensor. Monocular vision provides an interesting application of vision in robot soccer because of cost concerns, but provides challenge in terms of video or image processing.

The question why there is a need to shift from global to local monocular vision is the need to have soccer robots which have the ability to do image processing and decision making. Currently the global vision system has a computer to do image processing and decision making, which is then transmitted to the soccer robots. Hence the robots do not possess any intelligence. Another reason for the creation of the guideline of parameters is that the current image processing for global vision has a huge capability whereas when the processing has to be done on-board the robot, image processing capability has many constrains.

In order to use monocular vision, a guideline of parameters has to be developed. This guideline will be based on the existing image processing requirement for vision system in robot soccer, namely the information obtained after the image processing in global vision systems. The information obtained after image processing in the global vision system are frame rate, color detection, shape or object detection and distance estimation. This requirement will be identified and applied to the monocular vision system guideline so as to achieve a desirable balance between performance and resources and the image processing will be implemented on-board a soccer robot which has very limited resources.

### 1.3 Problem Statement

Before diving farther into the thesis, the definition of each term of the title will be explained. The definitions for the term are;

- ‘guidelines of parameters’ is a basic structure or requirement of an underlying system,
- ‘local’ denoted the placement of a device on individual robots,
- ‘monocular’ is the application of a single vision device,
- ‘vision system’ is a device used for the purpose of providing the ability to see, specifically focused on the use of cameras,
- ‘MiroSoT’ is an abbreviated term for Micro Robot Soccer Tournament, which is the oldest and popular league in robot soccer.

Grouping it to gather, the title’s definition is a basic structure or requirement that utilizes a single front facing camera system attached on-board each robot in a MiroSoT league. The gist of the issue is the image processing requirement, the experiments conducted and finally the suitable video processing parameters to have a balance between performance and reliability.

The requirement here will be

- **Frame rate** – to obtain a real-time video processing capability similar to biologically inspired vision system, the frame rate has to be as high as possible. The higher frame rate produces better real-time data but the requirement of a minimum frame rate so that it can be declared as real-time will be review and established.
- **Color detection** – the ability of the video processing to classify colors so that it can differentiate the object detected based on color codes.