MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE 493-DESIGN STUDIO 1

PROPOSAL REPORT

COMPANY NAME: REVOLUSYS

PROJECT NAME: GIMME FAST

PROPOSED STARTING DATE: 02.11.2019

PROPOSED DURATION & COMPLETION DATE: 6.5 MONTHS/ 15.05.2020

COST OF THE PROJECT: 200 USD

REPORT SUBMITTED TO: DR. EMRE ÖZKAN

DATE OF SUBMISSION: 01.11.2019

revolusys

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1. EXECUTIVE SUMMARY

In this era we are all aware of that accessing to information has a crucial importance, but the more important and challenging part is how to transfer that information. Although RF transmission has been the conventional mean of data transmission up to these days, due to the increasing mobile data transmission RF technologies started to struggle on resolving our needs. In addition to the highly occupied bandwidth RF technologies suffer from speed, security and power efficiency problems. The best way to accomplish these problems is using a revolutionary method: visible light communication.

As Revolutionary Systems we will design an image transmission platform where VLC is combined with data transportation by a vehicle. The system will consist of two end terminals that can receive or transmit an image as data packets while a vehicle rushes between these terminals to handle the long distance transmission of the data. While combining communication and transportation the main purpose is to transfer an image as accurately as possible in the shortest time. For achieving this goal the main tasks and our solutions approaches can be listed as:

- Data Compression and Division into Data Packets
    - Compression of image data to enable faster transmission
    - Division of the image data into smaller matrices to get smaller data packets
- Visible Light Communication
    - Sending and recieveing light signals by LEDs and photodiodes
    - Modulation of the original signal for communication
    - Filtering in order to cancel noise
    - Use of preamble signals for handshaking between receivers and transmitters
- Data Transportation by Vehicle
    - Control of the vehicle on physically guided tracks
    - Distance detection by IR proximity sensor
    - Transceiver unit placed and memory chunk on the vehicle

Even though handling all these tasks require knowledge from a diversity of electrical engineering areas, our team contains engineers specialized in the areas of communication, computer, electronics and control. Thus, a correct division of labor between us enables us to handle this big task as smaller and manageable problems and come up with a competitive product build upon the skills of each member.

Our company aims to build up a fast and accurate system for the minimal cost while taking physical robustness and the immunity of the system to variable conditions into account. The project is planned to be finished in 6.5 months with a total budget of about 130$.

As the end product, a vehicle that is moving on a physically guided track with a transceiver on it and two end terminals which are a transmitter and a receiver will be delivered. In addition to these, a camera to take the photo and a display will be supplied to the customer with a user manual and two years of warranty.

This document is a proposal report of the described product which contains further information on how the product will be developed.

2. INTRODUCTION

Radio spectrum is used to transmit data wirelessly for an enormous amount of daily services including but not limited to TV and radio broadcasting, mobile phones, Wi-Fi communications, GPS and radar. The global mobile data traffic has increased by 71 percent in 2017 according to the yearly report of CISCO [1].In addition, the increasing device connectivity because of IoT also puts more load on RF bandwith. Hence, the ever increasing demand for huge amount of information, faster communication and higher quality data, it is crucial to note that the usable radio spectrum is a scarce source where exponentially growing demand surpasses the supply. Apart from the narrow and already highly occupied bandwith problem, some other issues with the convenient communication systems can be explained as security problems, power inefficiency and interference.

A recently developed communication method which is known as VLC (visible light communication) has a potential to solve these problems. Since VLC uses visible light, the bandwidth is increased tremendously, it is in between 430 THz to 790 THz [2]. Also, since the VLC receiver receives the signal only if the transmitter and the receiver are in the same room, it is more secure than RF communication. What is more, since a visible light source can be used for both illumination and communication, it saves extra power when compared to RF communication.

The professors of Electrical and Electronics Engineering in METU has requested from us to design a system which can transfer data via two complementing technologies, transportation and communication. The design will be completed by Revolusys Inc. Which consists of five senior year engineering students in METU.

Although, there are existing communication architectures, they suffer from the aforementioned inefficiencies. A need exists for new communication methods. The design possesses a physically guided vehicle and a VLC system. The goal is to transport a picture from one terminal to the other terminal as fast and accurate as possible while keeping the cost minimal.

By accomplishing this project, we will prove that a VLC system integrated with a transportation vehicle is implementable and this, in turn, will lead to a widespread use of the visible light spectrum. This will allow us to operate on a completely empty frequency band which will increase the amount of data transmission to a greater extent. Therefore, the entire society will reap the benefit of increased and more reliable data transmission and live in a more connected world.

3. TEAM ORGANIZATION

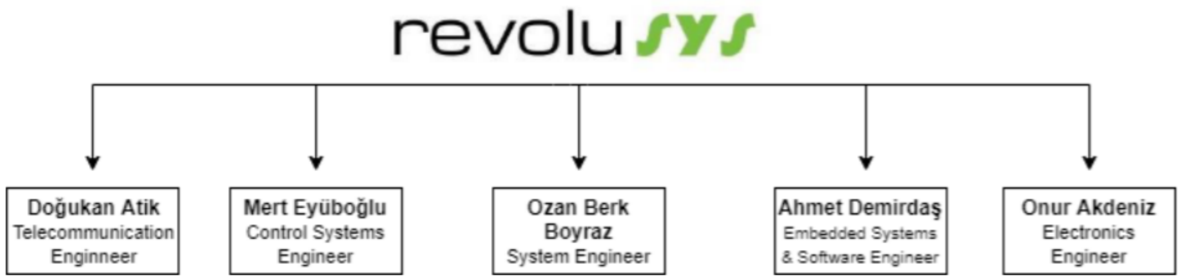

Figure 1. Company Organization

Revolusys is a company which conducts the ‘’Gimme Fast ‘’ project. Revolusys consists of 5 senior engineering students from different specialization areas. Each member of Revolusys has different skills on different areas. In our company, tasks has been shared with respect to the talents of each engineer.

Doğukan Atik is the Telecommunication engineer of Revolusys. He is experienced in MATLAB and also he has a past working experience in communication systems algorithm design. Additionaly, he excels at signal processing. Hence, he will mainly be interested in algorithm development for the communication systems. Mert Eyüboğlu is Control Systems

Engineer of Revolusys. He conducts his studies on Control Area. He is knowledgeable at control systems design and he is skilled at building up the required circuitry and coming up with feasible and innovative solutions for the design of such systems. Therefore, he is responsible from finding solutions to the stable operation of the mechanical parts of the project and design of the vehicle in general. Ozan Berk Boyraz is the system engineer of the company. He is from electronics option. In addition, he is also expert at mechanical design and integration. Therefore, combining this skill with electronics domain expertise, he will mainly be responsible for the hardware aspects of the project and integration of sub-modules. Ahmet Demirdaş is from Computer area. He is the Embedded Systems & Software Engineer of the Revolusys. His skills covers embedded system programming and object oriented programming languages such as C++. Therefore he will be responsible for high performance microcontroller application development. Onur Akdeniz is the electronics engineer of the Revolusys. He is from electronics area. He is also physics major student. Being a double major student, he has a deep knowledge of optics and light-guiding structure design. Therefore, he is responsible from designing the physical layers of the communication system.

4. REQUIREMENT ANALYSIS

4.1 Functional Requirements

- The system must be able to take a photo.
- Some portion of the photo must be transmitted to the vehicle by VLC (Visible Light Communication).
- The vehicle should go to the receiver terminal on a physically guided track.
- The data packets carried by the vehicle needs to be delivered to the receiver terminal.
- The vehicle must go back and forth until the transfer of the full photo is done.
- As the full photo is delivered, the photo must be displayed at the receiver terminal.

4.2 Performance Requirements

- A minimum DTR (data transfer rate) of 0.013 Mbps will be achieved.
- The average velocity of the vehicle shouldn’t be lower than 25 cm/sec for the maximum distance case (1.5 meters).
- The minimum accuracy rate of 90% should be achieved for the reconstructed image.

4.3 Physical Requirements

- The vehicle should be able to move on a physically guided track.
- The receiver terminal will also be able to move on the track.
- The distance between two terminals should vary between 0.4 meters to 1.5 meters.

4.4 Objectives

Revolusys Inc. defined the design objectives as it is shown on the objective tree, Figure 2. For the weights of each objective, the binary comparison is formed and its results are added to the objective tree. The detailed information about the scales of each objective and the binary comparison for weight calculation is given in the Appendices (9.2. Objective Selection).

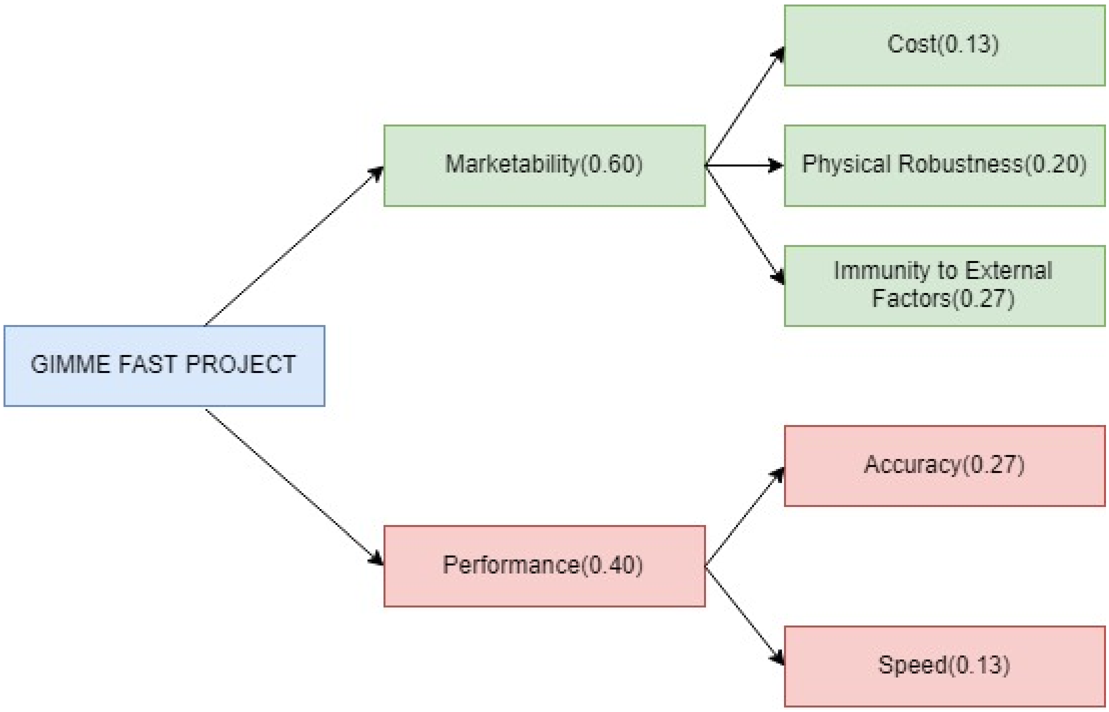

Figure 2: Objective Tree Including the Weights for Each Objective

4.5 Constraints

- There must be 5 cm between transmitter and receiver during the light communication.
- Maximum time for the total data transfer is 2 minutes.
- Microcontroller’s memory shouldn’t exceed 10 kB.
- Data transfer must be handled with 5 full round.

- Up to 8 LEDs and 8 photodiodes/LDRs can be used in the whole system.
- The distance between two terminals should be convertible up to 1.5 meters.

5. SOLUTION PROCEDURE

5.1. SOLUTION APPROACH

To develop a solution approach we first must clearly identify problems that are required to be solved in order to complete this project.

The fundamental tasks that should be completed are storing the digital image, applying compression algorithms on the image, division of the compressed image into smaller data packets, transferring data packets to the vehicle from the source terminal via VLC, controlling the movement of the vehicle on the rail, transferring the data packets to the receiver terminal again by means of VLC, image reconstruction from the received data and finally displaying the image that is transmitted.

At the source terminal, a Raspberry Pi 3-5MP camera module will take the photo when enabled by a push button. The taken photo will be sent to Raspberry Pi 3 general purpose computer to be stored. Then the image will be compressed and divided into smaller packets such that maximum size of each data packet will be 10 kB.

For the data transmission between the vehicle and the terminals, Li-Fi (light fidelity) technologies will be used. The color data corresponding to each pixel will be transmitted to the vehicle by using visible light produced by low cost LEDs and a receiver built up of photodiodes will capture the data either to transfer or process it depending on whether it is the receiver on the vehicle or at the end terminal.

In order to send the data through visible light, it first needs to be modulated by either a multi frequency shift keying or phase shift keying method. By using MFSK, different frequency values corresponding to each symbol will be determined. Here, each symbol represents a binary number. Therefore, the frequency spectrum will be allocated accordingly to use the maximum number of carrier frequency which, in turn, will increase the data rate.

A method of communication should be enabled between all receivers and transmitters so that the receivers may identify when the transmitter is sending the image data to them and when they are capturing just irrelevant noise. It is also necessary to identify when the data transmission is finished so that the received data packet will be stored. A preamble signal will indicate the start of the message and another signal will indicate the end of it. When the end of the message signal is received, the vehicle can start moving.

Transportation utilized by vehicle is as important as communication, thus good control of the vehicle has a crucial role on the overall performance of the system. Whether the car is receiving or transmitting a packet, the vehicle must head up to the next station as the data transfer ends. To do so, it should accelerate until it reaches to a predefined maximum speed and then it should continue to its motion towards the next station with constant speed. When the distance between vehicle and destined station is shorter than a predefined threshold distance, the vehicle must realize that it’s arriving to the station and decelerate properly so that it stops at least 5cm away from the station. To sense the station, the vehicle must obtain distance data from a sensor. To achieve this, it is planned to use an IR triangulation proximity sensor which calculates the distance according to the angle of a reflected IR beam from a surface. This selection is made due to lightweight structure and competitive price point of IR triangulation proximity sensor. As alternatives to selected sensor, a laser distance sensor or an ultrasound proximity sensor can be used. After reaching its destination, the vehicle will begin receiving or transmitting data by using its transceiver. To control the movement of the car and its communication with the terminals, an Arduino microcontroller will be placed onto the car.

As the receiver terminal receives a data packet it must immediately begin to reconstruct image in order not to waste any time. To do this the received signal will first be demodulated so that the information carried in the signal is obtained. Later the demodulated data must be decompressed and the values corresponding to each pixel will be reconstructed.

After the whole image data is transferred to the receiver the image will reconstructed. However, since the data we obtained passes through a noisy communication channel, the image obtained will be distorted. Therefore, various filtering techniques such as median filtering or low pass filtering must be applied. Finally, the system will display the transferred image on a 3.5inch LCD display.

To tackle this design problem, we have several facilities in our disposal. The company will use the design laboratory located in METU Electrical and Electronics Engineering E block for product development. Other than that, for software development, the company owns several PC’s in which the MATLAB and Python coding will take place.

5.2. ESTIMATED SCHEDULE

At the beginning, fundamental research will be conducted. Based on the fundamental research, required components will be listed and shopping will be done. After shopping, component tests will be conducted for detecting possible defected components. Then, sub-level system design starts. During the design stage, research on specific topics such as communication systems, vehicle system, image compression & reconstruction issues and Arduino & Raspberry Pi basics will be conducted.

Before the module demo, construction of communication circuitry and algorithms and construction of vehicle and its control system starts and image compression and reconstruction module will be completed. Besides, alternative solution methods will be sought. Construction process is long enough for trying different solutions and making changes if necessary.

After module demo, conceptual design report will be submitted and oral presentations will follow them.

Then, test setups will be constructed for sub-module optimization and overview. After the optimization process, integration of sub-systems comes.

During the integration process, overall system will be tested and optimized. Note that this is the most important and longest part of the project. After this step, device will be produced and will be ready for demonstration.

This whole schedule is presented also as a Gannt Chart in the Appendices (9.4. Gannt Chart). At the Gannt chart of the project, each period represents 1 week starting from 4 November 2019.

5.3. TEST PLANS

5.3.1. Communication System Test Plans

In the beginning, the system's ability to send and receive a predetermined signal should be investigated. First, the transmitter and receivers should be placed 5 cm apart from each other. Then, an artificially generated sinusoidal signal at a constant frequency should be fed to the transmitter part. Next, the signal at the receiver side should be observed with an oscilloscope and it should be verified that the sinusoidal signal is successfully received.

Next, the system's ability to send and receive an artificially generated message signal should be observed. First, the binary message signal should be given to the system. Then, the output signal should be controlled. The output signal and input signal should match.

The communication system should be able to recognize the start of the message and end of the message signal. Therefore, a controlled message signal with beginning of the message and end of the message signals attached to its beginning and end of it should be sent to the transmitter. However, there should be some random signal before the beginning indicator and after the end indicator. In summary, the message signal should look like this:

Message signal = random signal + beginning indicator + actual message + end indicator + random signal

Then, the output should be observed. The goal is to see only the actual message signal.

The communication system should be fast. To measure its speed, a message signal of known memory occupation should be sent via the transmitter. The amount of time it takes to see the entire message signal at the receiver side should be recorded. Then, the data rate can be calculated.

5.3.2. Image Compression, Decompression, Reconstruction and Data Slicing Test Plan

The camera part of the system should take a picture, compress it, and then slice it to the pieces of 10 kB. The testing of the algorithms responsible for these operations will be tested on a computer, and then they will be embedded into a Raspberry Pi.

To achieve this goal, first it must be ensured that the system can slice the picture and then reconstruct it. For that purpose, the picture should be divided into pieces using the developed algorithm for it. After that, the pieces should be given to the reconstruction algorithm and the image should be reconstructed. After that, the original image and its reconstructed version should be inspected visually and their corresponding image matrices should be compared numerically. There should be no error at this stage since there is no compression yet.

After the successful completion of this it, the same test should be tried by adding the compression and decompression algorithms to it. The visually inspected picture file and its reconstructed version should be as similar to each other as possible.

5.3.3. The Vehicle Test Plan

The vehicle should be able to go back and forth between the end terminals within one minute. The vehicle should be able to accelerate and decelerate properly for the varying distances between the terminals and stop at a minimum distance of five cm away from the terminals. Therefore, first, a start signal should be sent to the vehicle. Then, the vehicle should start moving. When the vehicle arrives at the next terminal, another move signal should be given to it so that it starts moving again. This way, the proper operation of the vehicle can be ensured.

Additionally, the same test can be repeated for the maximum for five consecutive times and the total travelling time can be recorded. This way, the average speed can be calculated and it can be seen whether it meets the average speed requirement.

5.4. BUDGET PLAN

The company has also noted down the estimated R&D costs considering each party involved in the project. The total estimated budget of the project is calculated as about 130$, the detailed list of required components and their prices are presented in the Appendices (9.3. Cost Analysis).

6. DELIVERABLES

6.1 Equipment

- *Vehicle*
  The user will be provided with a vehicle which has a transceiver embedded on it. The transceiver unit includes 4 LEDs and 4 photodiodes. The vehicle is able to detect the terminal and accelerate or decelerate accordingly.
- *Physically Guided Track*
  The user will be provided with a 1.5 meters long plastically constructed rail on which the vehicle can move.
- *Transmitting Terminal*
  The user will be provided with a rectangular prism shaped transmitting terminal which contains a camera, to take a photo, transmitter unit which consists of 4 LEDs and its own computational unit.

- *Receiving Terminal*

  The user will be provided with a rectangular prism shaped receiving terminal which contains a receiver unit consisting 4 photodiodes, a 3.5 inch LCD screen to display the taken photo and its own computational unit.

6.2 <u>Documents</u>

- *Warranty*

  Revolusys Inc. provides two (2) years warranty in both transportation and communication breakdowns of the system except the user faults.
- *Manual*

  A manual will be provided to the users to get informed about the utilization and the maintenance of the system.

7. CONCLUSION

Revolusys Inc. will design a system which is mainly consisting of communication and transportation. In today's world, humanity is covered by devices generating radio waves like mobile phones, wireless internet connections etc. Internet users are increasing while the use of WiFi is increasing. Therefore the load on RF bandwidth increases day by day. In addition, since they penetrate through the walls, RF waves suffer from security issues. Therefore Revolusys Inc will use VLC (Visible Light Communication) ,a new technology that is using visible light to transfer data. With a fast and robust transportation vehicle, data transfer will be handled in a more secure and faster way.

The problems to be solved are quite accurate; transferring the data from the source terminal to the vehicle, designing the vehicle such that it will have a convertible acceleration according to the length of track and transferring the data packets to the receiver terminal. Also it will be required to handle these processes in a fast and robust way. Taking all the solutions for these topics into consideration, Revolusys Inc. will have a deep R&D work on each subsystem of the project and implement the total system.

As a consequence of this project, the world will gain a new approach on the communication and data transfer. The lighting of lamps will not be sufficient to the mankind!

8. REFERENCES

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9. APPENDICES

9.1. PROJECT SELETION

Table 1: Binary Comparison of Objectives Generated for Project Selection

	A	B	C	D	E	F	G	GRAND TOTAL	ADD 1	Weighted Total
A)The amount of mechanic skill required	-	0,5	1	0,5	0	1	0	3	4	0.14
B) Suitability of the project to the skills of group members	0,5	-	0,5	0	1	0	0	2	3	0.11
C) Excitement that project creates on project members	0	0,5	-	1	0,5	0,5	0,5	3	4	0.14
D) Variety of the possible solutions	0,5	1	0	-	0	1	0	2,5	3,5	0.13
E)Testability of the project and the submodules	1	0	0,5	1	-	1	0,5	4	5	0.18
F) Clarity of the project requirements	0	1	0,5	0	0	-	0	1,5	2,5	0.09
G) Possibility of finding implemented solutions	1	1	0,5	1	0,5	1	-	5	6	0.21

The objectives for the projects are specified by the Company members and the weights of the objectives are found by binary comparison. Table 1 shows the weights of all objectives.

Table 2: Objective Metric

	A(0.14)	B(0.11)	C(0.14)	D(0.13)	E(0.18)	F(0.09)	G(0.21)	TOTAL
Cat Feeding	2 (0.28)	2 (0.22)	3 (0.42)	3 (0.39)	2 (0.36)	2 (0.18)	3 (0.63)	2.48
Gimme Fast	4 (0.56)	4 (0.44)	3 (0.42)	3 (0.39)	4 (0.72)	5 (0.45)	3 (0.63)	**3.61**
Autonomous Valet	1 (0.14)	3 (0.33)	3 (0.42)	4 (0.52)	3 (0.54)	3 (0.27)	3 (0.63)	2.85
Where Am I?	3 (0.42)	3 (0.33)	3 (0.42)	4 (0.52)	2 (0.36)	3 (0.27)	2 (0.42)	2.74

As a result of objective metric, Revolusys Inc. selected “Gimme Fast” project for Engineering Design course.

9.2. OBJECTIVE SELECTION

Table 3: Binary Comparison of Design Objectives

	Cost	Physical Robustness	Immunity to External Factors	Accuracy	Speed	Grand Total	Add One	Weight
Cost	-	0	0	0,5	0,5	1	2	0.13
Physical Robustness	1	-	0	0	1	2	3	0.20
Immunity to External Factors	1	1	-	0,5	0,5	3	4	0.27
Accuracy	0,5	1	0,5	-	1	3	4	0.27
Speed	0,5	0	0,5	0	-	1	2	0.13

Design objectives are defined and by means of binary comparison, the weights of them are calculated. Table 3 shows the weights of all objectives.

The objectives are scaled so that the company can assign points to the alternative designs and find the best-matching design considering the company's milestones.

<u>Performance Objectives:</u>

Speed:

- 5 points – Operation time under 60 seconds
- 4 points – Operation time between 60 and 75 seconds
- 3 points – Operation time between 75 and 90 seconds
- 2 points – Operation time between 90 and 105 seconds
- 1 points – Operation time between 105 and 120 seconds
- 0 points – Operation time over 120 seconds

Accuracy:

- 5 points – The displayed image has %100-85 accuracy
- 4 points – The displayed image has %85-70 accuracy
- 3 points – The displayed image has %70-55 accuracy
- 2 points – The displayed image has %55-40 accuracy
- 1 points – The displayed image has %40-25 accuracy
- 0 points – The displayed image has under %25 accuracy

<u>Marketability Objectives:</u>

Cost:

- 5 points – Total cost is under 100$
- 4 points – Total cost is between 100-125$
- 3 points – Total cost is between 125-150$
- 2 points – Total cost is between 150-175$
- 1 points – Total cost is between 175-200$
- 0 points – Total cost is over 200$

Immunity to Variable Light Conditions:

- 5 points – Works under sunlight.
- 4 points – Works under indoor lightening.
- 3 points – Works at shadows at daytime.
- 2 points – Works under indoor shady lightening.
- 1 points – Works unsteadily under shady indoor lightening.
- 0 points – Works only under complete darkness.

Robustness:

- 5 points – System is robust for its operation and transportation of the system.
- 4 points – Risk of disintegration of several parts of the system while packing and transporting whole system to another location.
- 3 points – Disintegration of several parts of the system while packing and transporting whole system to another location.
- 2 points – Risk of disintegration of one part of system in operation time.
- 1 points – Disintegration of one part of system in operation time.
- 0 points – Disintegration of several parts of system in operation time.

9.3. COST ANALYSIS

Table 4: Prices of Components

EXPENSE ITEMS	COSTS
2 x Raspberry Pi 3 (To be used in receiver and transceiver terminals)	410 TL
Arduino Uno + Vehicle Kit with DC Motor Driver (to implement the vehicle with microcontroller embedded on it)	152.5 TL
Raspberry Pi 3 Camera Module (to take the photo at the transceiver terminal)	16 TL
8 x LED (to be used for VLC at the transceiver terminal and on the vehicle)	1 TL
8 x Visible Light Sensitive Photodiode (to be used for VLC at the receiver terminal and on the vehicle)	12 TL
3.5`` LCD Screen (to display the reconstructed image at the receiver terminal)	50 TL
Others(Jumpers, breadboard, PCB, plastic pipes(to be used for rail construction))	100 TL
TOTAL COST	**741.5 TL (130.2 $)**

9.4. GANTT CHART

Project Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1

Plan Duration

ACTIVITY	PLAN START	PLAN DURATION
Fundamental Research	1	1
Component Listing and Shopping	2	1
Component Tests	3	1
Sub-System Level Design	2	4
Research on Communication System	2	4
Research on Vehicle System	2	4
Research on Image Compression& Reconstruction Techniques	2	4
Research on Arduino& Raspberry Basics	2	4
Construction of Communication Circuitry and Algorithms	3	9
Construction of Vehicle and its Control System	3	9
Alternative Solution Methods Development	3	4
Implementation of Image Compression& Reconstruction Module	4	2
Sub-Module Tests	4	5
Module Demo	6	1
Conceptual Design Report	7	1
Oral Presentation	8	1
Preparation of Test Setups	9	2
Sub-Module Overview & Optimization	11	5
System Integration	14	6
Overall System Test & Optimization	16	11
Critical Design Report	18	1
Final Report	27	1
Demonstration	28	1
KKM Project Fair	33	1

PERIODS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35