Contents

1 Introduction

1.1 Summary

1.2 Field of application

This project relates to an industrial monitoring system. More specifically the main application of the developed device is to monitor, in real time, the position of a point machine.

A point machine is an electric motor driven switch that enables an operator to switch a train from one railroad track to another. The main elements of a switch are the points. Figure 1 shows the points in the normal position (top) and in the reverse position (bottom). When the points are in normal position the train, which goes from left to right in this diagram, continues by the same track. In the other hand, when the points are in reverse position the train changes from one track to another.

Nowadays point machines are typically operated from a remote location. Because their closure is imperative it has a device to inform the operator about its current position. The most common realization of this device consists on two lock bars, as we can see in figure 2. The motor is connected to the drive bar through gears. At the other end of the bar there are two points, or switch rails, attached to it. Each point has a lock bar attached to it. These lock bars go from the points to the engine. In the engine side there are two lock blades, one for each bar. When the points are in normal position the first lock blade locks one bar and when the points are in reverse position the second lock blade locks the other bar.

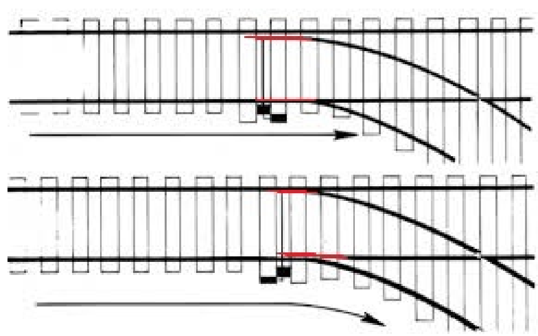

Figure 1: Points in a railroad switch. Normal position in the top and reverse position in the bottom.

When the operator moves the motor causes the linear and perpendicular movement of the drive bar. In turn, this causes the points to move and change their position. The points drag the lock bars which they are attached to. Inside of the engine housing, the lock blade locks the lock bar corresponding to the side where the points are. This produces an electric signal that informs the remote

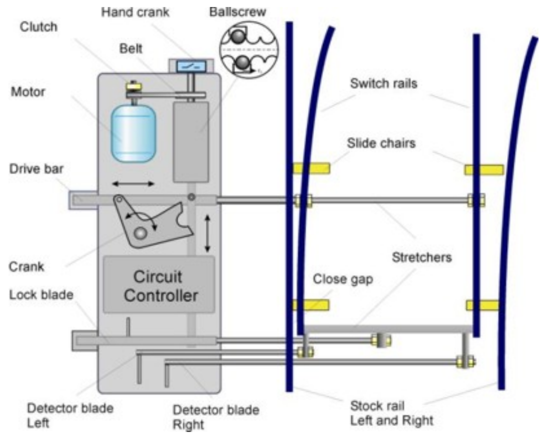

Figure 2: Parts of a point machine

operator that the switch has been successfully completed. When the lock bar does not arrive to its final position the electric circuit remains opened so the position of the switch is unknown and the operator cannot operate the switch. Security rules establish that a train cannot pass trough an intersection where the point machine is in an unknown position. This affects directly the railway traffic in a high demand network like a subway or the suburban train.

Although the position of the point machine is the only information required from the point of view of railway safety it is not enough from the point of view of the maintenance of a big number of point machines. There exists devices like the one described in [1] which uses inductive proximity sensors or [2] which uses a transformer with two coils to detect the position of the bar. There exists another device researched by the UPC and developed by Thinking Foward XXI SL that monitors all the signals available in the point machine including the exact position of the lock bars. This device is part of a system that will be further explained in chapter 2.

1.3 Goal

The goal of the present project is to develop a device to monitor the exact position of the lock bars. Furthermore there are some requisites that this device has to accomplish.

1. Easiness to install. In the railway sector there is very limited period of time to do the maintenance tasks during the night where there is no operation of the service, therefore it is very important that the developed device to be very easy and quick to install.

2. Robustness. Sometimes point machines are in the exterior subject to bad weather, dust and humidity. Although the device will be installed inside of the motor housing it has to be robust to this unfavorable conditions.

3. Precision. It is very important that the developed solution gives exact measurements with high repetitiveness. The gap to be measured in the lock bar is of few millimeters, so the desired precision of the measurements is between 0.1mm and 0.5mm.

4. Reduced execution time. As it will be explained in chapter 4 there are two modes of operation. In normal operation there is a window of 10 seconds to give the measure. In continuous operation the device has to be able to give at least one measure per second.

We will have these points in mind in order to do the design of the device in chapter 4.

1.4 Planning

Figure 3 shows a summary of the Gantt Chart of the project and figure 4 shows a more detailed planning of the phases and tasks. There are 5 people in the design and development team. This has been taking into account to establish the duration and planning of the tasks.

Projects where both, hardware and software, are involved are very hard to plan because sometimes there are several iterations in the hardware design. At the beginning of this project there is a first prototype with a basic functionality that consists on taking pictures and sending them to the Server. I have been involved in the hardware design, schematic and layout, and also in the firmware development of this prototype. Because of this, the planning of this project is more realistic and the hardware design is shorter than in other projects.

All members of the team are multidisciplinary but mainly the hardware team includes 3 people and the software and firmware team consists on 2 people. My tasks are mainly in the software and firmware development although as I have previously explained I have also been involved in the hardware development of the prototype which will be taken as the starting point of the final device. In order to make it more clear, I have marked in red the tasks where I will be actively involved in figure 4.

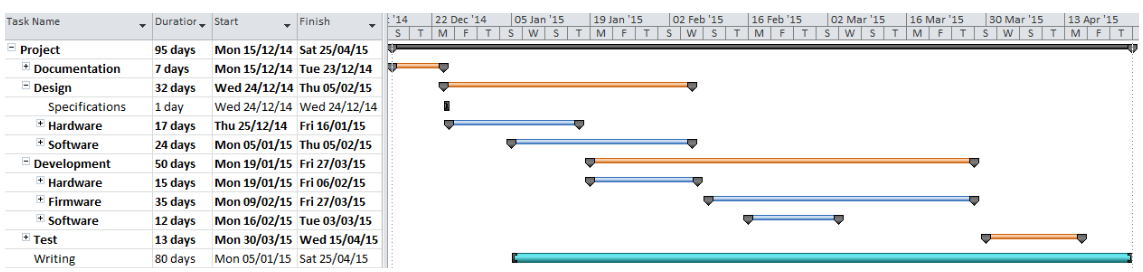

Figure 3: Planning. Gantt Chart Summary

Task Name	Duration	Start	Finish
Project	**95 days**	**Mon 15/12/14**	**Sat 25/04/15**
Documentation	**7 days**	**Mon 15/12/14**	**Tue 23/12/14**
Prior Art	5 days	Mon 15/12/14	Fri 19/12/14
Fundamentals	3 days	Fri 19/12/14	Tue 23/12/14
Design	**32 days**	**Wed 24/12/14**	**Thu 05/02/15**
Specifications	1 day	Wed 24/12/14	Wed 24/12/14
Hardware	**17 days**	**Thu 25/12/14**	**Fri 16/01/15**
PCB	**15 days**	**Thu 25/12/14**	**Wed 14/01/15**
Schematic	10 days	Thu 25/12/14	Wed 07/01/15
Layout	5 days	Thu 08/01/15	Wed 14/01/15
Mechanics	2 days	Thu 15/01/15	Fri 16/01/15
Software	**24 days**	**Mon 05/01/15**	**Thu 05/02/15**
Communications Protocol	4 days	Mon 05/01/15	Thu 08/01/15
Image processing prototype	20 days	Fri 09/01/15	Thu 05/02/15
Web client integration	1 day	Mon 05/01/15	Mon 05/01/15
Installation program	1 day	Tue 06/01/15	Tue 06/01/15
Development	**50 days**	**Mon 19/01/15**	**Fri 27/03/15**
Hardware	**15 days**	**Mon 19/01/15**	**Fri 06/02/15**
PCB	10 days	Mon 19/01/15	Fri 30/01/15
Housing	15 days	Mon 19/01/15	Fri 06/02/15
Firmware	**35 days**	**Mon 09/02/15**	**Fri 27/03/15**
Image processing library	25 days	Mon 23/02/15	Fri 27/03/15
Image sensor configuration	15 days	Mon 09/02/15	Fri 27/02/15
Communications Protocol	20 days	Mon 02/03/15	Fri 27/03/15
Software	**12 days**	**Mon 16/02/15**	**Tue 03/03/15**
Web client integration	2 days	Mon 02/03/15	Tue 03/03/15
Installation program	5 days	Mon 16/02/15	Fri 20/02/15
Test	**13 days**	**Mon 30/03/15**	**Wed 15/04/15**
Laboratory measurements	3 days	Mon 30/03/15	Wed 01/04/15
First installation	10 days	Thu 02/04/15	Wed 15/04/15
Writing	80 days	Mon 05/01/15	Sat 25/04/15

Figure 4: Planning. Tasks detail. The tasks where I have been actively involved are marked in red.

2 Prior Art

2.1 Computer vision in industrial applications

2.2 Magnetic gap measurement

2.3 Embedded computer vision

3 Fundamentals

3.1 Segmentation

3.2 Binarization

3.3 Camera calibration

4 Design

4.1 System specifications (according to the goals)

4.2 Hardware design

4.3 Custom communications protocol over CAN

4.4 Image processing. Matlab prototypes

4.5 Gap measure display

5 Development

5.1 Hardware constraints

5.2 Image processing library

5.3 Image sensor configuration

5.4 Communications protocol

6 Results

6.1 Accuracy and repetitiveness

6.2 Image vs magnetic sensor

6.3 On site measurements

7 Conclusions

7.1 Goals review

7.2 Future work

References

[1] Raymond C. Franke. Railway Switch Machine Point Detection System. Union Switch & Signal, Inc., assignee. Patent US 6382567 B2. 25 Aug. 1999.

[2] Mark Alan Hager, Michael F. Towey, Jr. Contactless point detection system for railroad switch. Alstom Signaling, Inc., assignee. Patent US 6427949 B1. 23 Jan 2001.