ENSC 305W/440W Grading Rubric for Functional Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the functionality of the proposed product without excessive design content (i.e., outlines the "what" rather than the "how").	**/10%**
Technical Correctness	Ideas presented represent valid functional specifications that must be considered for a marketed product. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text).	**/15%**
Process Details	Complete analysis of problem. Justification for chosen functionalities. Sources of ideas referenced. Specification distinguishes between functions for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Comprehensively details current constraints.	**/20%**
Engineering Standards	Outlines specific engineering standards that apply to the device or system and lists them in the references.	**/10%**
Sustainability/Safety	Issues related to sustainability issues and safety of the device are carefully analyzed. This analysis must cover the "cradle-to-cradle" cycle for the current version of the device and should outline major considerations for a device at the production stage.	**/10%**
Conclusion/References	Summarizes functionality. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow in a logical manner.	**/05%**
Format Issues	Includes letter of transmittal, title page, executive summary, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
Comments		

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October 14, 2013
Mr. Sjoerdsma
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Re: ENSC 440 Functional Specifications – Digital Auto-Focus with Shifting Sensor

Dear Mr. Sjoerdsma,

This package contains Motus' functional specifications for our Image Sensor Shifting System (ISSS) for cameras. Our group is currently in the process of building a camera prototype that makes use of a mobile image sensor that can achieve auto-focusing without having to shift any glass lenses.

The attached document outlines the functions of our project in a variety of systems ranging from software, to hardware, to the optical system. In addition, we also cover topics ranging from sustainability to safe practices and procedures.

If you wish to discuss our project in further detail, or have any questions or concerns, please feel free to contact me via email at jpa30@sfu.ca.

Sincerely,

Jeff Priest
Chief Executive Officer
Motus

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Image Sensor Shifting System for Cameras

Functional Specifications

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Revision

1.0

Executive Summary

Motus' Image Sensor Shifting System is being designed to provide photographers with an alternative means of achieving auto-focus, even if their preferred lens doesn't natively support it. After doing an exhaustive market search for a camera that has this feature, and discovering that none currently exist, we decided to develop a prototype that would be able to demonstrate this.

When designing our prototype, we needed to come up with a list of the various functions that the camera would be able to perform, both on the system-level, and on the user-level. The system-level functions listed in the following document cover many of the low-level requirements of our project, as well as any standards that we must adhere to when moving into the design portion of our project's development. The user-level functions will outline the goals of our prototype, and what we hope to be able to provide to the end-user in terms of camera features.

Currently, Motus is working on multiple systems with the goal of being able to demonstrate an early proof-of-concept. Progress is being made in the optical system, image processing software, and system integration. In addition to these areas, we are collectively assessing our sustainability model and exploring ways to improve it as the design, development and testing continues. As these areas are explored, we are constantly revising our functional specifications and these changes will be reflected in future documents.

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Glossary

ASL – Above sea level

Capture time delay - Time between pressing the exposure button on a digital still camera

ISSS – Image Sensor Shifting System

Mbps - Megabits per second

PCB – Printed circuit board

STP – Standard temperature and pressure (typically 15^{o}C and 101.325 kPa)

Vignetting – Blurred or darkened edges around an image

Table of Contents

Table of Figures

1. Introduction

Motus' Image Sensor Shifting System (ISSS) introduces an alternative method of achieving auto-focus for cameras. The primary objective of the device is to let camera users use manual-focus lenses to perform auto focus. The ISSS is designed to move an image sensor inside the camera instead of moving the focal glasses inside a camera's lens attachment. Figure 1 demonstrates the shifting technology implemented in the ISSS, where the sensor (yellow line) shifts to achieve a focused image

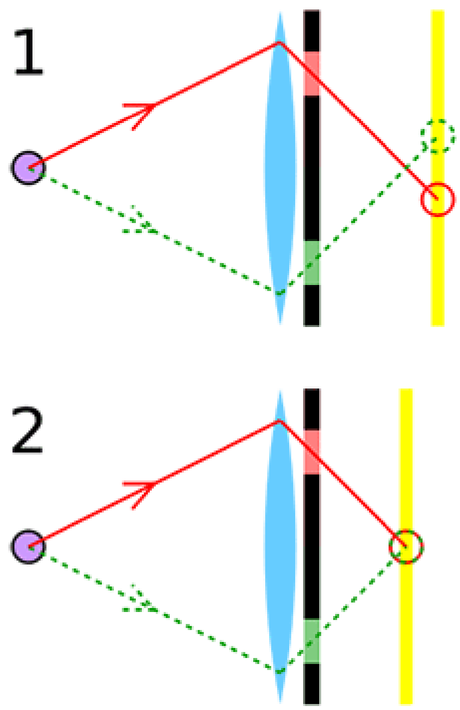

Figure 1 – Sensor shifting to achieve a focused image [8]

The advantages of the shifting the image sensor instead of the lens are numerous. Lenses manufactured in the future will be smaller without sacrificing image quality. The lens will not require a motor and focal glass, and it will be cheaper to manufacturer. The detailed functional requirements will be listed later in this document.

1.1 Scope

This document lists the functional requirements that Motus' Image Sensor Shifting System (ISSS) must meet at the end of development duration. In addition, we outline how the ISSS adheres to the general Engineering Standard set by CSA and ISO standards. The listed functions are in a state of constant revision, and the requirements listed herein apply to a proof of concept product.

1.2 Intended Audience

The functional specifications for Motus' Image Sensor Shifting System (ISSS) are intended to be shared among the members of Motus and will serve as a reference for analysis and testing. Motus will refer to this document to satisfy any concerns as to the functionality of the product, and execute test plans to assess the functionality of the product.

1.3 Classification

Throughout this document, the functional requirements will be presented in the following manner:

[Requirement#-Priority]

Priority 1 items show the basic functionality of the product, and are required items in the proof-of-concept. Safety considerations will all be priority 1 items.

Priority 2 items are requirements that must be included in a functioning prototype.

Priority 3 items are requirements that must be included in the final product. Requirements under priority 3 may not be included in the proof-of-concept or prototype phases of this project.

2. System Requirements

2.1 System Overview

The ISSS can be broken down as follows:

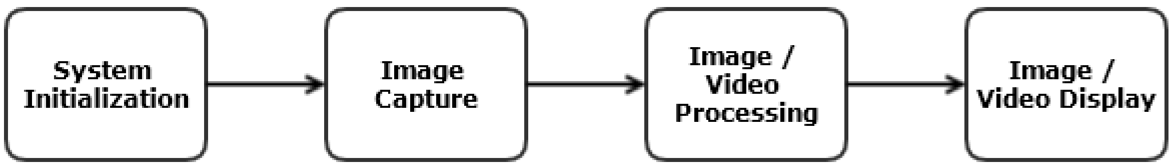

Figure 2 – High level system overview

The system consists of camera lens, imaging sensor, mechanical shifting platform and microcontroller. For our prototype, the user can use any type of camera lens to fit into our system and perform auto-focus while taking pictures, no matter if the user's lenses have built-in auto-focus feature. After user gives our system the model of lens being used, the computer will find out the flange focal distance of this lens. The image sensor will be moved to this flange focal distance along a linear rail, then start to record image around that position. Once the image sensor transfer the image to computer, image processing algorithm will be involved to calculate which image has the highest focus strength value. The microcontroller will send feedback signal to motor, then the motor will drive the image sensor to best location for most focused image. Figure 3 shows the system overview diagram.

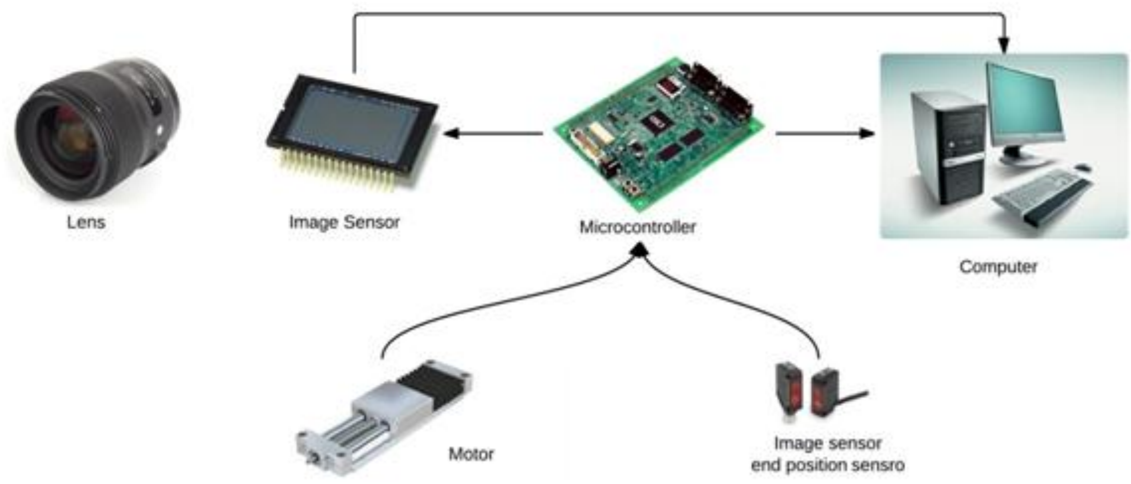

Figure 3 – System overview diagram

2.2 General Requirements

[R1-1] User can turn on the system by clicking ON button.
[R2-2] The system will check the function of each sub-system on start up.
[R3-3] The start up time should takes less than 3 seconds.
[R4-1] The user can turn off the system by pressing the OFF button.
[R5-2] The system will move all components to the default status after the user presses the OFF button.
[R6-1] The system will capture the image when the user presses the "capture" button.
[R7-1] The capture time delay of proposed system should be less than 2 seconds
[R8-3] The capture time delay should be measured based on requirements of ISO 15781:2013. [1]
[R9-3] The system should have an exposure index, ISO speed rating, standard output sensitivity and recommended exposure index, and these features should be satisfy ISO 12232 [2].
[R10-3] The user can select a target on a display screen to be the subject of auto-focusing
[R11-2] The user can fit most modem camera lenses onto the ISSS.
[R12-1] The system should perform auto-focus with any lenses installed.
[R13-3] The price of the ISSS should be comparable to other DSL cameras on the market.

2.3 Physical Requirements

[R14-2] The length of the ISSS should not exceed 200mm.
[R15-2] The height of the ISSS should not exceed 100mm.
[R16-2] The width of the ISSS should not exceed 200mm.
[R17-2] The weight of the ISSS should not exceed 2000g.

2.4 Electrical Requirements

[R18-1] All electrical components must be properly grounded.
[R19-2] All PCBs must be protected by a fuse.
[R20-2] The system should require a 12V DC power supply.
[R21-3] The system battery should be charged by 110V-230V 60Hz AC.
[R22-3] The system should be able to use a memory card and USB cable to store image data.
[R23-1] All electronics must be CSA approved.

2.5 Mechanical Requirements

[R24-1] None of the mechanical moving parts should be accessible by a typical user.

2.6 Environmental Requirements

[R25-1] The system should be able to operate under STP conditions.
[R26-2] The operating temperature of the system should be from 0^{o}C to 40^{o}C, values which are based on operating parameters for a Nikon D4 camera. [6]
[R27-2] The operation humidity of system should be from 5% to 80%, these values are based on operating parameters for a Nikon D4 camera. [6]
[R28-3] The system should operate between an elevation of 0m to 5000m (16,405’) ASL.

2.7 Safety Requirements

[R29-1] The failure of any component of the system will not cause any injuries to the user.
[R30-1] The system should have a hard stop mechanism to prevent a mechanical control failure.
[R31-1] The electronic components should not cause any interference with other devices.
[R32-3] The system should be able to detect a mechanical or electrical failure and notify the user.
[R33-1] The system should not overheat or cause a fire.

2.8 Performance Requirements

[R34-3] The focusing speed should be equal to or faster than 0.65s. [10]

2.9 Engineering Standards

[R35-2] The system should be compliant with ISO 15781:2013 in regards to the capture time delay measurement. [1]
[R36-2] The system should be compliant with ISO 12232:2006 in regards to the exposure and ISO speed measurements. [2]
[R37-2] All electronics, connections and cables should be compliant with CSA Canadian Electrical Code in regards to safety. [3]

2.10 Reliability and Durability Requirements

[R38-3] The ISSS should be designed for long term use (a minimum of 5 years).
[R39-3] The ISSS should be maintained by trained technicians.
[R40-3] The ISSS should be resistant to breakage when dropped from a height of less than 1m.

3. Optical Lens Requirements

The primary function of the optical lens is to project images onto the image sensor.

3.1 General Requirements

[R41-2] Lenses are interchangeable. Lens should be able to be snapped on and removed by users

[R42-1] Lenses should be 35mm format in order to project a 36mm x 24mm full frame image onto an image plane, since this type of lens is most commonly used and widely available in the market.

3.2 Physical Requirements

[R43-1] Lenses should have an aperture mechanism to control the depth of field and depth of focus.

[R44-1] Lenses should have no mechanical or electronic connection with the main system enclosure.

[R45-2] Lenses should have a relatively large maximum aperture value to allow enough light going through to produce bright images.

[R46-2] Lens flange focal distance should be no longer than 91.3mm since the "Leitz Visoflex I" lenses have the longest flange focal distance in the market. [5]

3.3 Performance Requirements

[R47-3] The lens should produce a sharp image without heavy vignetting.

4. Imaging Sensor Requirements

The primary function of the image sensor is to capture an image based on a user's request (via pressing a button, or some other means), and then be able to transmit that image to the microcontroller for processing.

4.1 General Requirements

[R48-1] The resolution of the image sensor should be larger than 1.3 megapixels in order to improve the efficiency of image processing.

[R49-1] The image sensor should provide a 64k color image for better image quality.

[R50-1] The image sensor should be able to output RGB image data for image processing.

[R51-1] The minimum data transmission rate should be larger than 12 Mbps to eliminating image processing idling.

4.2 Physical Requirements

[R52-1] The size of the image sensor with a PCB should be less than 50mm x 100mm.

[R53-2] The image sensor should be able to fit onto the shifting carriage.

4.3 Electrical Requirements

[R54-1] The imaging sensor should be able to work with a power suply rated for less than 12V.

[R55-3] The power consumption of the image sensor should be less than 1W at the operating voltage.

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5. Image Shifting and Enclosure System Requirements

The primary function of the image shifting and enclosure system is to move the image sensor to the desired location and provide a dark environment for image capturing. The shifting system is the only moving mechanism inside the ISSS. The enclosure also needs to protect inside components from physical impact. The following figure shows the basic model of the image shifting platform.

Figure 4 – Motorized platform for image shifting [7]

5.1 General Requirements

[R56-1] The image shifting system should provide linear motion to move the image sensor.

[R57-2] The motor vibration should neither damage the image sensor, nor should it cause any image quality degradation.

[R58-1] The full step angle of the stepper motor should be less than 3.6^{o} for precise motion.

[R59-2] The motor friction must be minimized in order to achieve higher linear precision.

[R60-2] The straightness tolerance of the rail should be less than 0.02mm for higher linear precision.

[R61-3] The energy efficiency of the shifting system should exceed 50% in order to reduce energy consumption.

[R62-1] Each step of the motor system should be less than 50µm to ensure a high degree of precision in linear sensor movement.

[R63-3] The speed of the shifting system should be larger than 100mm/sec in order to remain within focus timing constraints.

[R64-2] The loading torque of shifting system should be larger than 1Nm during regular operation speed in order to carry the image sensor.

[R65-3] The step angle accuracy should be larger than ±5% (full step, no load) for higher precision motion.

[R66-3] The enclosure must provide a completely dark environment for the image sensor in order to attain higher image quality.

[R67-3] The enclosure must be insulated in order to protect the electronics inside.

5.2 Physical Requirements

[R68-2] The length of the rail should not exceed 100mm based on the flange focal distance of current DSL camera lenses on the market.

[R69-2] The length of the enclosure should not exceed 150mm.

[R70-2] The height of the enclosure should not exceed 100mm.

[R71-2] The width of the enclosure should not exceed 200mm.

5.3 Safety Requirements

[R72-1] Two sensors must be installed on each end of the track in order to stop the motor when it reaches either end.

[R73-1] Lockout will be applied when testing the shifting system.

[R74-1] There are no cables or other components along the rail path. Care will be taken to ensure that no cables can accidentally cross the track.

6. Microcontroller Requirements

The primary function of the microcontroller is to control the motor and to provide a means of transmitting the image sensor data to the machine that will perform the image processing.

6.1 General Requirements

[R75-1] The microcontroller should facilitate real-time feedback control.
[R76-2] The firmware on the microcontroller must be bug free.
[R77-2] The microcontroller must be protected against electrostatic discharge during installation.
[R78-3] The microcontroller should have a failsafe built in, in case of a malfunction in one of the subsystems.

6.2 Electrical Requirements

[R79-1] The microcontroller should not consume more than 20mA in its active mode.
[R80-1] The operating voltage of the microcontroller should not exceed 12V.
[R81-1] The output voltage should be able to drive the stepper motor.
[R82-1] The bandwidth of the microcontroller should be at least 60MHz.

7. Image Processing Requirements

Image processing will be used to analyze the image sensor's captured data, and calculate the strength of a given frame's contrast.

7.1 General Requirements

[R83-1] The image processing step should calculate the contrast strength of each image.

[R84-2] The image processing step should use at least one focusing zone or point on an image.

[R85-3] The user should be able to chose which object is to be focused.

[R86-1] The image processing step should find image with highest focus strength value, and display that image to the user.

7.2 Software Requirements

[R87-3] The maximum processing time should not be more than the time required to move the image sensor from its initial position to the away position.

[R88-3] Image processing should adhere to the requirements set by ISO/IEC 12207. [4]

8. Sustainability and Safety Overview

8.1 Safety

[R89-1] The electrical components will be isolated from interference from the end-user.
[R90-1] Any internal wiring as well as critical system components will be enclosed.
[R91-1] The power cable and / or external display cable(s) will be accessible to the user via a small opening in the enclosure
[R92-2] Surge protectors will be used for any high-voltage tests
[R93-2] The device will operate using a 12V DC power supply
[R94-1] The mechanical moving parts will be hidden from the user, and will not be accessible without a set of tools.

8.2 Sustainability Model

Motus is taking great care to develop a sustainability model that takes into consideration the lifecycle of its ISSS product. We consider the following key areas:

- Reusability of materials as technical nutrients
- Social responsibility and the global social capital
- Economics

In regards to the reusability of our product, we will look at the main 4 systems that comprise the ISSS: the optics system, the software, the micro-controller and other hardware components, and the physical enclosure.

Since our product is being designed to be adaptable to different lens attachments, we can treat the external optics system as a separate entity and only consider the internal optics. Any internal lenses or image planes can be recycled and re-used for optics in other projects that Motus may undertake in the future. This will be made possible by mounting these objects in non-permanent ways (as opposed to using glue or solder for example), and instead using proper mounting fixtures within the enclosure. The exact mounting fixtures to be used are still under consideration and will be explored further in future documents.

The software system is inherently reusable, and may be used in future projects that Motus may undertake. This gives us an economic advantage by allowing us to re-use and re-factor any of the software used in this project for later projects or revisions without having to start from scratch.

The hardware used in this project will be primarily selected with the intent of finding the most cost-effective components that meet our design goals. Since the goal of any business is to generate profit for the shareholders, we must make sure that any hardware choices (namely, the microcontroller and motor) are carefully selected to maximize revenue. In our prototype design, however, we may focus more on the functionality of the components, and their ability to meet our technical requirements rather than their cost-effectiveness in mass-production.

The product's enclosure will be constructed from recycled scrap metal from Kodak Canada. This meets all three of the areas in our sustainability model. We can recycle the enclosure when the end of the product's lifespan is reached, or treat it as a technical nutrient that may be used in future projects. This is economic as well, since it will cut down the cost of materials used in subsequent projects or revisions. As Motus grows and expands into new areas, this will become an even larger issue, and the matter of recycling old components will need to be dealt with. One way in which we might do this is be enlisting the help of local communities – either through direct employment, or by seeking the help of recycling facilities and potentially becoming partners. Our goal is to increase the social capital not just within Motus, but in surrounding communities and in industry.

9. Conclusion

This document has outlined the functional requirements that must be met by the prototype being developed by Motus. The systems are divided into their constituent parts, each with set requirements. Design and development is still ongoing, and each member of Motus is striving to build a functional prototype which will meet as many of the requirements outlined in this document as possible. The prototype is expected to be completed by early December 2013.

10. References

[1] "Determination of Exposure Index, ISO Speed Ratings, Standard Output Sensitivity, and Recommended Exposure Index." ISO 12232:2006. N.p., n.d. Web. 17 Oct. 2013. <http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=37777>

[2] "Measuring Capture time delay, Shutter Release Time Lag, Shooting Rate, and Start-up Time." ISO 15781:2013. ISO, n.d. Web. 17 Oct. 2013. <http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51326>

[3] CAN/CSA-C22.2 No. 0-M91 (Reaffirmed 2001) General Requirements - Canadian Electrical Code, Part II, 2001, CSA Group.

[4] "Software Life Cycle Process Assessment Model." ISO/IEC 15504-5:2012. N.p., n.d. Web. 17 Oct. 2013. < http://webstore.iec.ch/preview/info_isoiec15504-1%7Bed1.0%7Den.pdf>

[5] "Lens Mount." Wikipedia. Wikimedia Foundation, 15 Oct. 2013. Web. 17 Oct. 2013. <http://en.wikipedia.org/wiki/Lens_mount>

[6] "Nikon | Imaging Products | Specifications - Nikon D4." Nikon | Imaging Products | Specifications - Nikon D4. Nikon.com, n.d. Web. 17 Oct. 2013. <http://imaging.nikon.com/lineup/dslr/d4/spec.htm>

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[10] "Canon EF 70-300mm F/4-5.6 IS USM Review." *Canon EF 70-300/4-5.6IS USM Lens Review*. N.p., n.d. Web. 17 Oct. 2013. <http://www.bobatkins.com/photography/reviews/ef_70_300is_review.html>