Motion Stage for Optical Coherence Tomography

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Abstract

Optical coherence tomography is a useful diagnostic tool in detecting conditions in the eye. In clinical settings, patients are often unable to move their eyes with the fine adjustment that optical coherence tomography requires to obtain images precisely. Consequently, the OCT machine, which is rather bulky, has to be moved. This task involves fine range motion in three dimensions (X, Y, and Z) as well as rotation around a central axis. To facilitate this, our design team used a fine range cross table capable of fine resolution movement in two directions (X and Y) along with a vertical table capable of motion in the Z-direction. Rotation of the device was accomplished by a central pivot point and a worm drive.

Introduction

Optical coherence tomography (OCT) is the ideal imaging modality when it comes to diagnosing degenerative conditions of the eye, such as macular degeneration. It is non-invasive, requires no special preparation either on the patients' or clinicians' part, and does not harm the patient in any way due to radiation. OCT uses the principle of interferometry to scan the patient's eye, so precision is an important factor during image acquisition (the broadbeam laser source measures in the range of 1000s of nanometers)[1].

The clinical relevance of OCT is enormous, especially to older patients, who tend to have many conditions affecting their eyes. Many of the patients at the clinic tend to be older, and may have difficulties performing the fine adjustments in position required for the technician to obtain the proper image. The situation is further compounded by the fact that the OCT machines themselves are rather bulky and cannot be easily moved. In addition, in imaging situations where the subjects are unable to move (as in animal tests) because they are sedated, it is difficult to move the machine to accommodate the new subject.

Technicians operating the OCT system find it difficult to maneuver these machines precisely in the case when patients are not able to. The OCT machines, as shown below, are quite large and cannot be easily moved by the technician. In terms of ergonomics, the joystick offers a friendly user interface because its function is intuitive. Duplication of this functionality for the Cirrus Model is of foremost importance for the project. The Cirrus model does have limited motion capabilities, but the movement is controlled through the computer and requires the technician to concentrate on how the machine is moving while performing tasks on the computer interface (the control interface are arrow buttons; when clicked on, the chin rest shifts). This diversion of attention on the clinician's part could result in improper positioning and ineffective runs of image acquisition.

Materials and Methods

The final design involves a fine adjust cross slide table capable of movement of the horizontal plane with a precision of 0.02 m. The OCT camera sits atop the cross slide table, allowing it to be adjusted in the horizontal plane. The cross slide is bolted to a rectangular base, which is supported by four ball bearing casters. The entire assembly sits on a table capable of adjustment in the vertical direction. The assembly weighs roughly 150 lbs and the casters allow the device to be easily moved around the vertical adjustment table. This set up can be seen in Figure 1. Additionally, there is a long metal

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rod bolted to the front of the rectangular device. At the other end of the rod is a 5.5 inch diameter gear. The gear is aligned with a worm drive which is attached to a motor bolted to the vertical adjustment table. When the device is not in use, the worm drive

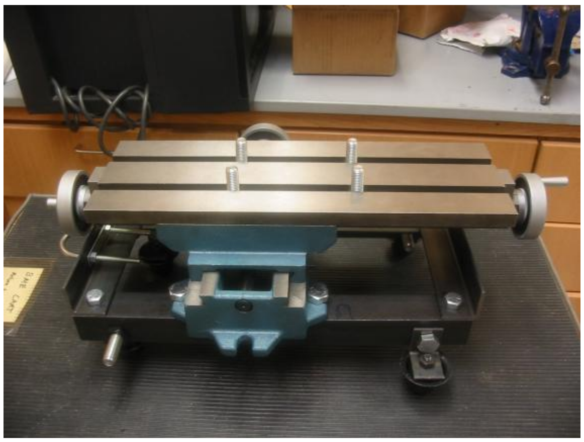

Figure 1: Final design without motorization

will stabilize the assembly but also allow the device to rotate when the motor is active.

Motorization of the device is accomplished through three robotics motors each capable of spin in both the clockwise and counterclockwise direction. Ideally, they would be attached directly to the shaft of the cross slide table through a coupler. However, the current design uses a two gear mechanism to increase the torque of the motors. A small gear is attached to the motor via a coupling bolt and screw. This gear turns a larger gear which is attached to the central shaft of the cross slide table. The larger gears are held in place by a nut placed on the end of the cross slide central shaft.

Each motor is attached to a motor controller, which controls the speed and direction of the motors. The motor controllers work of the principles of pulse width modulation to control the motors. The three motor controllers are run to an RC receiver which allows all the controllers to be operated from a single device. The receiver is controlled by a remote transmitter with two, two axis joysticks. Each axis controls a different motor, allowing horizontal motion in two directions as well as rotation.

Testing

Two separate types of tests were done with the cross-slide table in order to assess its effectiveness and the improvement over the current adjustment system. Both tests were run to compare the amount of time that will be needed by the user to adjust the table to the correct position for imaging. Currently, the person operating the imaging device may need up to fifteen minutes to align the camera to the position required for accurate imaging, and the main goal of this project is to significantly decrease that amount of time.

The first test focuses on the comparison from manual adjustment to adjustment using the manual cranks on the cross slide table. The test was run nine times, and each test involved moving the table a random distance and measuring the amount of time it takes to adjust the table per inch. One tester turned the table at a moderate and consistent pace, while another timed the process. The results were plotted and can be seen in Figure 2

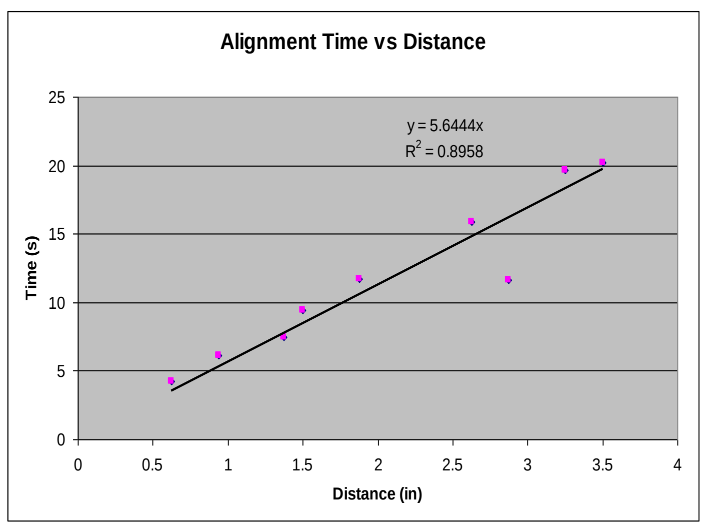

Figure 2: The amount of time required to adjust the table

The graph shows that it takes approximately five seconds to move the table one inch. Considering the fact that the adjustments made during the imaging procedure are often very minute, this is a significant increase in time efficiency over the current system.

The next test focuses on the comparison between the speed of moving the table with the hand crank and moving it with a motor. Each trial involved moving the table its entire span in one direction at a fast pace with the hand cranks and then moving it its entire span using a motor. This was repeated for a total of ten trials. The results can be seen in Figure 3.

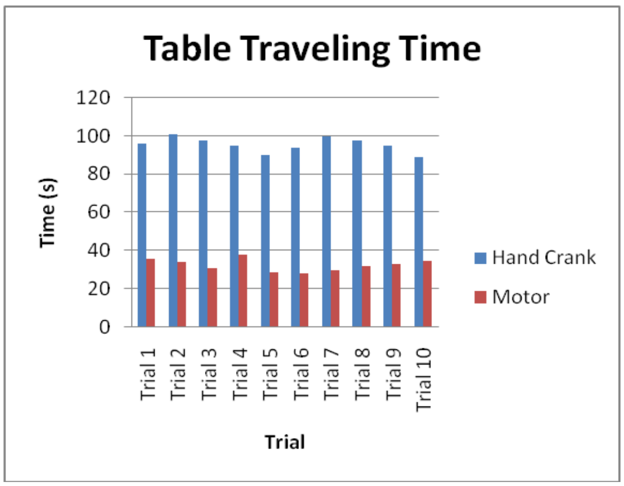

Figure 3: Ten trials moving the table its entire span using both the hand cranks and the motor.

It can be seen from the graph that using the motor takes only about 1/3 of the time to move the table across its entire span when compared to the hand cranks. The average amount of time needed for the hand crank was 95.6 s and the average amount of time needed for the motor was 32.6 s.

Ethical Concerns

The design involved no major ethical concerns during construction. However, since the device will be used in a clinical setting, it is important to consider how the device will interact both with the personnel and the patients involved. During animal imaging studies, the animal will be anesthetized. Therefore, the travel of the table should be the only motion involved. During the study, the animal's safety should not be compromised. This can ensured by constraining the table's motion so that it is slow. This also applies to clinical procedures involving people. Another concern is how the device will function in a clinical environment. When considering human factors, one has to account for how easily the device is operated. Thus, intuitiveness of the device's function is very important. As specified by the client, a joystick mechanism would be appreciated for this purpose. The user interface thus becomes graphical and requires no further instruction (the current crank mechanism may be harder to implement). Future work will involve testing to determine which method works for clinicians.

Conclusions and Discussion

Currently, the device is configured with motors in the horizontal plane and has a rotation mechanism allowing for circular movement about a focal point directly in front of the lens of the imaging device. The motors can be easily set up to be controlled by an RC transmitter, using the motor controllers and an RC receiver. This will allow the user to control all three degrees of motion from one central, wireless controller. The design provides a very efficient means of operating the table which will significantly decrease the amount of time required to align the camera.

The cross-slide table was designed and constructed to meet the needs of the user. It was designed in a way that allows switching of cameras on the table, keeping in mind that the client owns and operates two separate cameras and may at times need to switch the camera that is currently be adjusted by the table. Because of this, there is opportunity for the table to be mass produced and used for labs using the same camera and having the same difficulty in adjusting it. It can be constructed with very minimal costs. Considering the fact that the motors, motor controllers, and RC equipment were the most expensive components, the device could be constructed without these things and just operated using the hand cranks. This will still decrease the time required for alignment significantly. Whether using the motors or just the manual hand cranks, this device creates a major improvement over the current system of adjustment.

References

1 Clin Experiment Ophthalmol. 2008 Sep 23. [Epub ahead of print] Links Ophthalmic imaging today: an ophthalmic photographer's viewpoint - a review.

Appendix

The appendix contains our PDS and pictures of the motor configuration

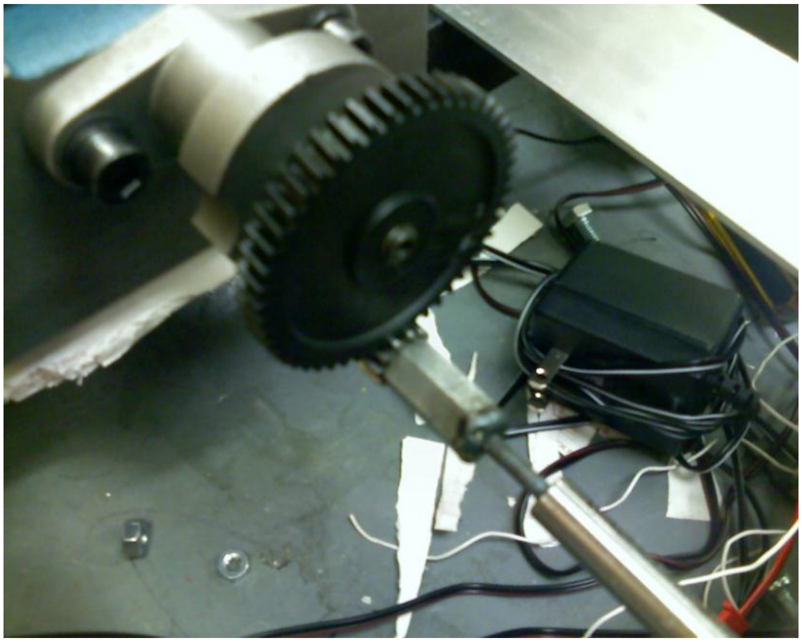

Figure 1: Two gear system for moving the device in one horizontal direction.

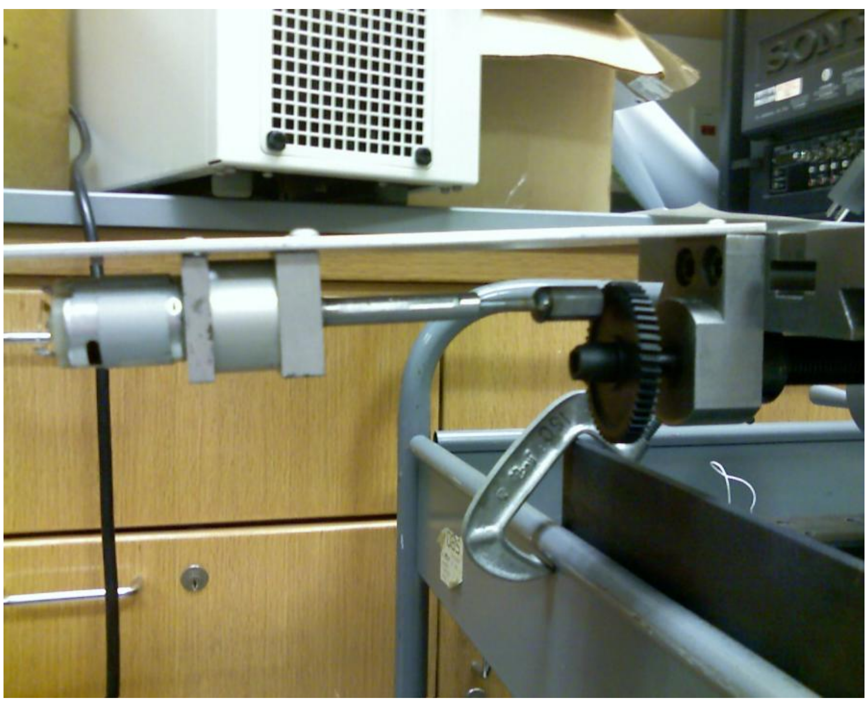

Figure 2: Two gear system for moving the device in the other horizontal direction. No gear is pictured two to it break during tapping.

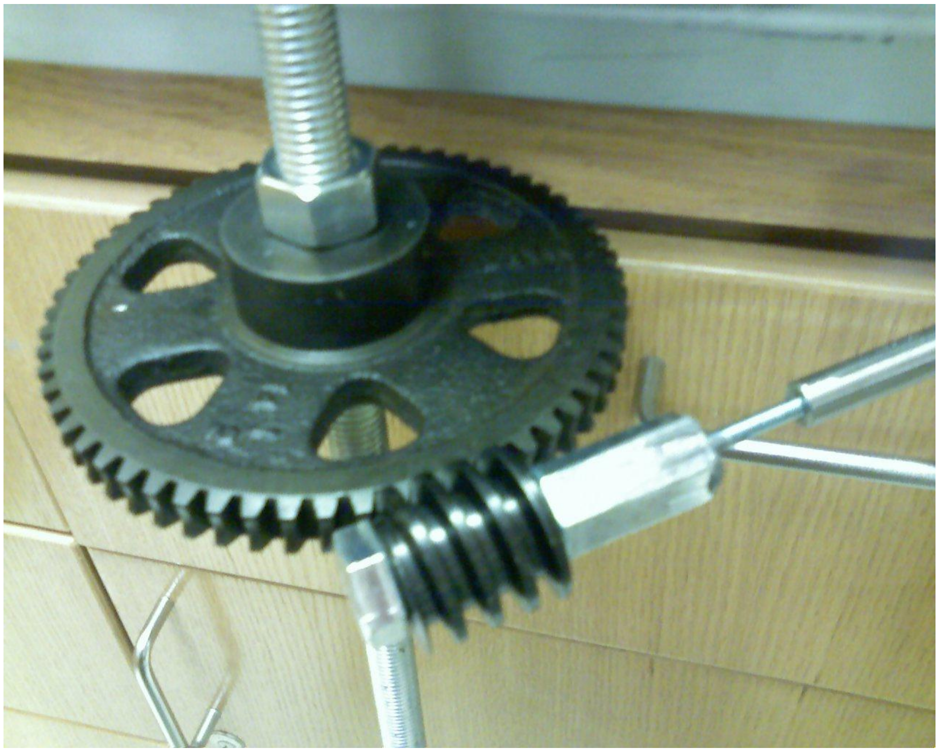

Figure 3: Rotation gear mechanism. The metal shaft is bolted to the table so that when the gear is spun, the table rotates.

Figure 4: The motor attachment to the rectangular base.

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Positioning/alignment device for ophthalmic scanning laser systems

Function

The device must be designed to position the 80lb. Cirrus-OCT ocular imaging device currently in use by the Ophthalmology clinic. While the clinic's current positioning system is capable of crudely positioning the OCT camera in the vicinity of the eye, it lacks fine positioning capability. This device we design must be able to refine the position of the OCT device by distances as small as a few millimeters. It must be able to position the camera in the horizontal plane, tilt the camera, and rotate the camera. The user interface for such fine movements must be simple, accurate, and repeatable, as is the joystick positioning device used for a different model of OCT camera currently in use at the clinic.

Client requirements:

- Height, angle, and tilt, and rotation adjustments
- Fine tuning of positioning
- OCT must be 2 inches away from the eye
- Preference for a joystick to adjust the instrument
- Must be used for both human and animal optical imaging
  Must be a device for supporting the OCT and not for positioning the head, for safety concerns

1. Physical and Operational Characteristics

a. *Performance requirements*: The device should be able to position the OCT at the correct height, angle, rotation, and tilt for proper optical imaging. The device will be used every time that the OCT is used, because the proper alignment will be different each time. It must support the weight of OCT and be able to lock into place once proper alignment is achieved.

b. *Safety*: The main safety concern is that the device must be able to support the weight of the OCT. The inability of the device to do this could cause injuries due to the falling or breaking of equipment.

c. *Accuracy and Reliability*: The device must be extremely accurate in order to be able to precisely align with the location of the eye that is to be imaged. This means that the device must be able to make very fine movements in height, angle, rotation, and tilt. Repeatability of positioning is desirable for when patients are imaged more than once.

d. *Life in Service*: The device will be used multiple times per day. It does not need to be designed to be mobile, because it will stay with the OCT at all times.

e. *Shelf Life*: The Ophthalmology Clinic uses the Cirrus-OCT on a daily basis. Because of this and its 80 lb. size, the Cirrus unit remains on the table in the clinic’s imaging room at all times. Because transporting the Cirrus unit off the table is difficult due to its bulk, our positioning unit will presumably remain beneath the Cirrus unit at all times, both during periods of use and non-use. Therefore, its shelf environment is the same as its operating environment and it must be designed to withstand any harsh conditions of this persistent environment.

f. *Operating Environment*: The imaging room does not have any water sources. It is kept at a room temperature and humidity typical of most clinical environments. Patients and doctors do enter and exit the room frequently, and doctors will presumably be using the unit multiple times per day, so the unit will most likely be exposed to a significant number of low intensity stresses on a daily bases, and more intense stresses on a less frequent basis.

g. *Ergonomics*: The device's motion control interface must be user friendly and not cause stress to a frequent user. Both patients and doctors will be in close proximity to the device's moving parts. Therefore, any moving parts must be contained so as to avoid pinching or crushing of patients' and doctors' extremities should inadvertent contact occur.

h. *Size*: There is no strict restriction on weight as the unit will be stationary. In terms of spatial dimensions, it must either have a footprint small enough to fit on the imaging room's camera table or it must be a stand-alone unit small enough to fit into the 8' x 8' imaging room.

i. *Weight*: The weight of the device must be light enough to allow rotation and movement in the desired directions. If the device is too heavy, the operator will have to apply a great amount of force to move the position, eliminating any chance for fine adjustments.

j. *Materials*: The materials used to construct the positioned will have to be strong enough to hold 80 lbs. They should be capable withstanding year of use. They should be of a weight that fits with the requirements presented in the weight category.

k. *Aesthetics*: The design of the device should allow for easy use by any operator. All adjustment knobs or joysticks should be clearly labeled with their function. If electronics are used, all wires should be housed in a casing so they cannot be seen or accidently pulled. The color should be matched to the room so that it does not draw the attention of the patient.

2. Production Characteristics:

a. Quantity: there are two units. For the Cirrus unit, we need to be able to incorporate rotational movement. For the Stratus unit, we need to design a system capable of lateral, rotational and vertical movement.

b. Target Product Cost: we need to be as economical about materials as possible.

3. Miscellaneous

a. Standards and Specifications: none

b. Customer: would prefer to control any movements through a joystick.

c. Patient-related concerns: for animal studies, correct positioning of the chin platform is necessary to avoid injury to the animal

d. Competition: Although platform positioners and machine arms exist for moving heavy objects, they have not yet been applied for this purpose. The cost of such devices is extremely prohibitive, as well, based on a number of factors (precision, material used to build the structure, etc.)