Mechanical System for Lifting and Turning Bound Pages
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ABSTRACT
Team Easy Reader accepted the challenge of designing and manufacturing a device to assist a person with cerebral palsy in the task of turning the pages of bound, printed material. In partnership with the customer, the team designed and constructed a prototype that consists of a platform to support the media, a rotating wheel mounted on a movable arm to create a space under the desired page to be turned and a mechanical linkage to advance the page. Data gathered from testing showed an increase in the rate of page turns, a reduction in the number of pages damaged, and a significant decrease in the physical demands placed on the customer compared to his current method of page turning. Based on these results, the team will refine the prototype for greater reliability and deliver a finished product to help the customer function better in his current position as minister, and to enable him to pursue additional employment opportunities.

BACKGROUND
Our engineering design team has selected a customer, Bill Adams, who suffers from moderate cerebral palsy (CP). Cerebral palsy is defined as “an umbrella term for a group of disorders affecting body movement, balance, and posture and is caused by abnormal development or damage in one or more parts of the brain that control muscle tone and motor activity.” CP is divided into three major classifications: spastic, dyskinetic and mixed. Spastic CP causes jerky and awkward movements due to increased muscle tone and stiffening and is responsible for 70% - 80% of all CP cases. Dyskinetic CP affects coordination of movement and encompasses the athetoid type, which results in uncontrolled movements that are slow and writhing and the ataxic type, which affects balance, coordination and often depth perception, impairing the ability to walk. [1] According to statistics presented by cerebralpalsy.org, 800,000 people have CP in the US with 2 to 3 children per 1,000 affected.[2]

The effects of CP have left Mr. Adams unable to turn the pages of printed material reliably. Mr. Adams has received a degree from Shawnee State University and is currently seeking employment in the city of Portsmouth, Ohio. However, it is difficult for him to find employment due to his inability to properly and efficiently consult reference materials. Also, Mr. Adams attends several career fairs and conferences where pamphlets and flyers are a primary source of communication. In addition, Mr. Adams is a member of several state advisory committees and a preacher of a church; all of which require the ability to read printed material of varying size and thickness.

When attempting to read a book or handout, Mr. Adams becomes frustrated as his jerky motions often cause the pages to be physically damaged, or cause several pages to stick together during the page turn, requiring another attempt at finding the right page and making the process an exhausting experience. Team Easy Reader, a team of five mechanical engineering seniors working on their year-long capstone design project, address these issues by designing, testing, and fabricating a semi-automated mechanical system to more reliably turn the pages of printed material such as magazines, work manuals, and books.

STATEMENT OF THE PROBLEM
There is a need for a device that is able to turn the pages of various forms of written media,
ranging from bound handouts to large reference books. The most important aspect of this device is that a user is able to operate the page turner without assistance from his care giver. For this reason, user friendliness and automatic operation are paramount to the design. Development will be based on the needs of a single client, Bill Adams, to allow him to read any bound materials that are presented to him during a board meeting, and to allow him to turn the pages in his bible without worry of damaging them while he is preaching. However, the device will be made universal to assist anyone who has trouble with the fine motor skills required to accurately turn a page.

RATIONALE

Based on Mr. Adams’ criteria, the final conceptual design for the device had to be portable, automated and most importantly safe for him to use. To ensure safety the device could not have any sharp edges or unprotected pinch points. Also, small moving parts such as the four-bar driving gears were covered. Due to the device’s portable nature, weight was restricted to 10 pounds or less to decrease the likelihood of injury if dropped. To allow Mr. Adams’ easy operation, the page turning mechanism had to be automated with the preference that one push of a button will turn one page.

During the design process, several specifications were determined including the size of the device, time to turn a page, and the target cost of the prototype. Many of Mr. Adams’ employment opportunities require the use of bound manuals, typically on 8.5 x 11in sheets of paper. To allow for flexibility, the size for the device was set at 14in x 18in with a 9in x 18in area to support the media. Currently, Mr. Adams’ condition greatly impacts the amount of time it takes him to turn a page. For this device a maximum page turn time of 7 seconds was allowed. Through research for this project it was discovered that there are several patents and current products on the market with retail prices ranging from $3000 to $5000 for. The maximum budget for this project was set to $500 for all manufacturing and parts associated with the prototype.

Although several options were considered for the page turning mechanism, based on tests carried out by the group it became apparent that a four-bar and wheel combination was the most effective combination. The two main factors that influenced this decision were that the wheel arm, when weighted correctly, is able to work on a multitude of paper types and will consistently lift only a single page and the four-bar mechanism moves in such a manner that it inserts under a lifted page consistently, minimizing damage to the page.

DESIGN

The final prototype design is shown in Figure 1. The device is powered by a rechargeable battery pack for portability, and has a built in charging port for convenience. The page turning mechanism consists of two main parts: the lift wheel and the four bar mechanism. The rotation of the rubber-surfaced wheel overcomes the static friction between pages, pushing the outside of the page toward the spine and causing it to form a parabolic shape. The four-bar mechanism then gets the signal to rotate, and the 4-bar’s slotted arm is inserted into the space under the parabolic arc of the page and continues to rotate in an elliptical path toward the center, causing the page to turn.

The page turner is activated by the push of a button. The user need only place the book onto the book plate and place the wheel on top of the starting page, either on the right side for paging forward or on the left for paging back. Pushing the button initiates the program written onto a PIC microcontroller, which sends a command to rotate the lift wheel and then initiate a sweep of the four-bar mechanism, thus turning a single page. The position of the lift wheel arm activates a position switch which sends a signal to the microcontroller to reverse direction of the turning
MECHANICAL PAGE TURNER


Our system design also includes the ability to change the angle of the reading platform according to the comfort needs of the customer. This also allows for easy reading in both table top mode, and the attachment of the reader to the customer’s wheelchair via a pre-existing mount. In addition, this allows the reader to be easily stored by folding flat which gives the system a profile of 4” tall, sliding easily under a chair or sofa.

The page turner was designed with safety in mind. Plastic guards were applied to the edges so the user would not get cut. It uses very little power, so there is no worry of an electrical shock and there is a failsafe in the angling mechanism so it will not crush/pinch the user’s fingers.

DEVELOPMENT

A 3-D model was created to ensure the proper fit and operation of all components and that the necessary motion could be achieved for turning pages. Finite element analysis was performed on the components to find failure points corresponding to theoretical maximum accidental loading situations. After successful analysis, a prototype was fabricated from the final CAD model.

The prototype development was focused around functionality with simplicity. The prototype was developed with features that would enable it to function correctly while still being able to be manufactured using standard machine tools. The material selection for the prototype was completed by finding a balance between cost, weight and material strength. This process resulted in a prototype constructed mainly from 5052, 6061, and 6063 aluminum. Some alternative materials that were considered include 1018 cold rolled steel and 18 gauge rolled steel sheet. Aluminum was chosen for its significant weight reduction and minimal increase in cost compared to steel. Aluminum also offered a lower overall product maintenance requirement for the life of the prototype since the aluminum will not have to be pretreated or coated to prevent corrosion. The fasteners that were selected for the prototype were all 8-32 button-head screws made of stainless steel. These allow proper attachment of the sheet metal to the aluminum structural members. The button-head screws also allow for easy disassembly of the prototype unit during testing. The only sections of the prototype where fasteners were not used included the corners of the bottom pan and
the 90° junction on the wheel arm, which were welded and ground smooth for aesthetics and strength. The costs of the materials used in the final prototype are presented in Table 1.

**Table 1: Bill of materials**

<table>
<thead>
<tr>
<th>#</th>
<th>Amount</th>
<th>Date</th>
<th>Component - Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$16.95</td>
<td>1/14/2011</td>
<td>Geared motors for testing</td>
</tr>
<tr>
<td>2</td>
<td>$11.95</td>
<td>1/24/2011</td>
<td>Wheel for geared motors</td>
</tr>
<tr>
<td>3</td>
<td>$102.35</td>
<td>2/14/2011</td>
<td>Electrical components</td>
</tr>
<tr>
<td>4</td>
<td>$32.51</td>
<td>2/22/2011</td>
<td>Fasteners</td>
</tr>
<tr>
<td>5</td>
<td>$74.56</td>
<td>2/3/2011</td>
<td>Aluminum Materials</td>
</tr>
<tr>
<td></td>
<td>Total $238.32</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EVALUATION**

The intent of this device is to assist our customer in the reading of books, manuals, and other printed material necessary for work related reading. It was very important that the customer not only be able to advance pages of the media but also be able to do so easily, and also be able to easily reverse the process and go backwards in the media. To this end, some innovative design measures have been implemented. The four-bar mechanism is innovative because it uses a machined slot in the longest link to change the path of the link from circular to trapezoidal, increasing the sweep length which improves its ability to turn a page. The pivoting arm whose location is determined by a position sensor allows the user to travel both forward and reverse into the media by simply placing the pivoting arm on the appropriate side of the page turner. By customer request this device was designed to be very robust. This has lead to a fairly large system which limits the practicality of the device with respect to portability. However, as a table top device the space requirement is not significantly greater than an average text book.

An initial estimate of the effectiveness of the page turner was determined with a set of comparison tests. For a benchmark, a one minute test was conducted to determine the rate at which the customer currently advances pages, the number of pages damaged, and the number of times two or more pages were turned. For comparison, the test was repeated with Mr. Adams using the page turning device. The results of the tests averaged for three different trials are presented in Table 2. This was the first time that Mr. Adams used the device to assist him in reading, as the simplicity of the device did not warrant a practice run. These results show that the device successfully increased the page turning speed and decreased the damage to the pages.

**DISCUSSION**

These results demonstrate that, as of the current design of the reader device, the customer can expect to receive an approximate 45% increase in page advancement speed when using a reference book, while reducing the subjective amount of damage to the media by 75%. Also, the physical strain of turning pages over even a short period of time left him very tired and uncomfortable, while using the reader the only interaction with the book is to press a button which does not cause any type of fatigue to the user.

It is expected that over the course of the next month, when we continue to make performance improvements, that the rate of pages turned will increase by 10% and the number of damaged page turns will be reduced so that the unit has at maximum a 5% occurrence of damage.
Table 2: Data comparing the customer's current abilities with his use of the page turner

<table>
<thead>
<tr>
<th>Method of Test</th>
<th>Unassisted Page Turning</th>
<th>Using Page Turner Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Test (sec)</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Pages turned</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Pages Damaged</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Multiple Page turns</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Exhaustion Level</td>
<td>High</td>
<td>None</td>
</tr>
</tbody>
</table>

REFERENCES


ACKNOWLEDGEMENTS

We would like to acknowledge the great contribution of our instructor, Dr. Kremer, who was able to provide us with the technical knowledge that was needed to successfully complete the project. We would also like to thank Randy Mulford for assisting with the manufacturing equipment and techniques that was required to properly build the device. We would like to thank our funding sources, most notably the grant awarded through the National Institute for the Severely Handicapped, and the funding provided through the Department of Mechanical Engineering at Ohio University.
Figure 1: This system consists of a flat 17”X15” aluminum plate with a lip approximately ten inches from the top of the plate to allow books to rest on the plate in a repeatable place. Below this lip is a gearbox with a motorized four-bar mechanism, which resembles a mechanical arm, which sweeps the page from one side of the book to the other. Below the gearbox at the bottom of the plate is an aluminum bar that extends from the center of the plate to the ¾ point with respect to the length of the plate. Attached to this arm is a motorized wheel coated in rubber which spins against the book causing the pages to fold slightly. This fold allows the sweeping four-bar to get under the page and turn it to the other side of the book.

This entire plate assembly is attached, by hinges, to a two inch deep pan that houses the computer chip controlling the reader operation and a turnable screw to allow the plate’s tilt angle to be adjusted from 60 degrees to lying flat in the pan.

All of the motions of the motorized elements are engaged with the push of a button on the plate and the power is controlled by a switch also on the plate.

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