Motorized Panorama Head

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**EXECUTIVE SUMMARY**

Optimal panoramic photography is essential in the field of virtual reality computer graphics. Digitally stitching together photographs to form a panoramic view requires precise camera positioning. The best panoramic photography is achieved when 50 percent of each individual photograph is overlapped.

The need for a more versatile method of taking panoramic photographs was the motivation for the design of the Motorized Panorama Head. The main objective for the system was to create a wider range of step angles from 1 to 90 degrees. This allows the user to specify the proper step size for any zoom setting to achieve the 50 percent overlap desired. The prototype is capable of measuring and displaying the horizontal field of view angle of the lens by utilizing microprocessor technology. Test results of the system show that it is capable of producing nearly flawless panoramic photographs by using a precisely measured overlap.

Current products offer limited positioning options. The Motorized Panorama Head provides a more convenient, reliable, and accurate method of generating panoramic photographs.
MOTIVATION FOR DESIGN

PROBLEM STATEMENT

The purpose of this project is to design a motorized panorama head that can be attached to a tripod using a standard 3/8” mount. The panorama head is capable of measuring and displaying the horizontal field of view angle of the camera lens. It also steps through equal angle steps as selected by the user, which normally are 50 percent of the camera’s horizontal field of view. The step sizes range from 1 to 90 degrees, with accuracy to the nearest degree. The device is also portable; therefore, it is battery operated.

BACKGROUND INFORMATION

The motivation for the Motorized Panorama Head is threefold. First, it minimizes error by eliminating estimation and interpolation associated with determining step sizes. Second, the step sizes are adjustable with a wide range of angles allowing for maximum versatility. Once the step size is set, it is fixed and precise. Third, the accuracy provided by the motorized head allows for convenience by reducing the work required to stitch together the panorama. By overlapping 50 percent of each picture with another, the panorama software will be able to stitch together pictures more easily.

Although there is an increasing demand for panorama heads, there are few available products on the market. Bogen makes the only professional panorama head found in production. This particular panorama head is purely mechanical and includes 10 different step sizes, with a minimum step size of 10 degrees. A few similar designs that utilized electronic technology have been discovered, but they do not have the versatility of the Motorized Panorama Head. One such design is an automated panorama head that utilizes electronic rather than mechanical technology [1]. This design has very limited capabilities and the smallest step size is 10 degrees. The Motorized Panorama Head goes the extra step by allowing the user to choose step sizes as small as 1 degree and as large as 90 degrees, so that virtually any camera and lens can be accommodated. As the zoom capacity on digital cameras improve, this feature of small step sizes becomes more significant. In addition, by incorporating a user keypad, this design
surpasses other designs in control and user convenience. The design also allows for better performance than competitors’ products due to its flexibility, high accuracy, and automation qualities.

**DESIGN SOLUTION**

The design of the Motorized Panorama Head started with a basic block diagram consisting of five parts. The block diagram in Figure 1 displays the layout of the proposed design.

![Design Block Diagram](image)

**Figure 1: Design Block Diagram**

Constraints were identified at the beginning and outlined the structure which the design followed. The parts were then selected based on how well they met those constraints. One important part of the block diagram was the microprocessor. A few manufacturability constraints were considered for the microprocessor’s software development. One constraint was the capability of code enhancement and correction without having to remove other hardware. Easy access to the microprocessor facilitates a more efficient way of updating the microprocessor when changes to the software are made. Another constraint involved using a standard microprocessor and development board that can be easily replaced. If the microprocessor became damaged, replacing it would not be a large or difficult task.
The next two parts of the block diagram were the LCD display and keypad. These components are essential tools to provide information to the user and offer control for the panorama-taking process. The LCD display required 5 V DC, and the data line required an inverter before the information was sent to the display unit. The keypad unit consisted of four completely passive switches. Both the LCD display and the keypad were backlight equipped. By incorporating the backlighting of these parts into the panorama system for low-light and nighttime operation, one of the environmental constraints was met.

The next part of the block diagram was the stepper motor. Stepper motors geared to one degree are rare and hard to find, but a motor with this specification was discovered. Most stepper motors have a step size of 1.8 or 0.9 degrees. If a motor with either of these step sizes were used, it would have to be geared in order to achieve a one degree step size. The process of gearing the stepper motor would have been a timely and costly process. By finding a motor already geared to one degree, the mechanics of the panorama head were simplified.

The stepper motor chosen for the design required 24 V DC to operate. This meant that a DC/DC converter was needed to elevate the system’s 9.6 V to 24 V. Power transistors were used as switches by the microprocessor to control the motor. Diodes were placed in parallel with each of the motor coils to provide a path for transient decay.

The last portion of the block diagram was the power supply. There were many constraints that factored into the design of the power supply. The first constraint was an environmental factor, implying that the system must be portable and use a battery pack. The second constraint was a sustainability factor, requiring that the batteries last a reasonable amount of time between recharges. Also, the batteries should have an acceptable lifespan and be replaceable with standard primary cells for situations when charging was not possible.
IMPLEMENTATION AND PROTOTYPE CONSTRUCTION

Prototype and Enclosure Construction

The construction of the prototype started after the decision matrices were completed for each portion of the block diagram. The decision matrices for each portion of the block diagram can be viewed in Appendix A. Most of the system parts were ordered the first week of December. No time was wasted on developing a prototype. A substitute stepper motor and a Motorola 68HC11 emulation board were used to start the implementation of a “dummy” prototype while the parts were being delivered. A basic prototype using an analog breadboard and power supplies was developed by the middle of December. A PCB (printed circuit board) that would house most of the system’s electronics was also being developed during this time. The first PCB was completed over Christmas break to replace the breadboard for a more portable system after the processor and converter arrived.

Most of the parts that were going to be used for the final prototype arrived by the middle of January. A fully functional prototype was running in the middle of January. The microprocessor had not yet arrived, so the development of the enclosures could not begin.

A new PCB was redesigned because the previous one would not fit inside the power supply box. Also, this new PCB included the pull-up and pull-down resistor connections whose purpose was previously undetermined. The pull-up and pull-down resistors were needed on the data and control lines of the microprocessor, otherwise the voltage levels floated around. The system was fully equipped and portable by the middle of February.

The handheld device was completed in the beginning of March. The power supply box experienced clearance problems and was not completed until the end of the month. Standard black plastic enclosures were used for both boxes. The holes were either drilled or punched out using a square punch. A rotary tool was used in both boxes to grind down the plastic portions that prohibited the mounting of the parts.
The wiring setup in both boxes was done in such a way that the lids could be fully detachable from the boxes. The handheld device required two different connectors in order to achieve this, whereas the power supply box required only one.

**Mechanical Head Construction**

In designing the mechanical portion of the Motorized Panorama Head, several criteria were considered. The unit needed to be capable of attaching to a standard 3/8” tripod mount and provide a 3/8” mount for the camera. The weight of the motor, camera, and other attachments needed to be supported by the head mount. It must allow the shaft to rotate freely without causing the motor to bind. Figure 2 shows the completed head mount. Mechanical drawings for the head mount can be seen in Appendix B.

![Figure 2: Mechanical Head Mount](image)

The final design of the unit involved mounting the stepper motor between two parallel 3/8” aluminum plates. These plates were precision cut to four inch squares using a computer controlled CNC Mill to achieve tolerances within a few thousandths of an inch. A 3/8”-16 tapped thru hole was cut into the center of the bottom plate to provide mounting to the tripod. A thru hole and a counterbore were milled into the center of the top plate using the CNC Mill to achieve tight tolerances. This allows for a thrust bearing to be inserted into the bottom of the top plate to allow a shaft to pass through and rotate with a minimum amount of friction. Holes were precision drilled a half inch from each side at the four corners of both plates. This is to allow four bolts to fasten each plate to standoff posts near the four corners. Also, the corner holes were countersunk to allow the
bolts to mount flush with the surfaces of the plates. The posts were lathed to lengths of 2.75 inches to produce proper spacing between top and bottom plates. They were tapped at each end to enable the selected bolts to fasten to them. Constructing the mount in this manner produces a durable unit. More importantly, the care taken in the precision ensures the shaft will pass through the top plate without rubbing or binding allowing it to rotate freely.

The shaft was custom made and cut from a length of a half inch diameter steel rod. It was lathed to a length of 1.625 inches. A portion of the bottom of the custom shaft was drilled out to allow it to fit tightly over the shaft of the stepper motor. The top of the shaft was lathed down to a 3/8” diameter to allow it to pass through the thrust bearing and the top plate. This was also done to cut 3/8”-16 threads into it to allow other standard size camera mounting equipment to be fastened to the Motorized Panorama Head unit. A setscrew was used to fasten the custom made shaft to the shaft of the stepper motor. The motor was carefully mounted to the bottom plate to center the shaft under the top plate. When completely assembled, the shaft is free to rotate with mounted equipment.

**ENHANCEMENTS**

Early construction of a working prototype allowed for the addition of many enhancements to the design. The enhancements improved such features as efficiency, convenience, and ergonomics.

The original design layout included the use of an optical emitter and detector pair to measure the rotation of the head with an encoder disk. This was excluded from the design by taking advantage of the microprocessor’s full capabilities. The microprocessor not only gave instructions to rotate the head, but also kept track of the position of the head.

Two indicator LEDs were added to the power supply box for user convenience. The first was a green LED that glows when the power switch is turned on. The second was a red LED that functions as a low-level battery indicator. As shown in Figure 3, a typical NiMH battery holds its rated voltage of 1.2 V for up to 80-90% of its life. The total rated voltage of the battery pack was 9.6 V. The battery indicator circuit was
designed to turn on when the combined battery pack voltage dropped to 8.5 V. This was accomplished with the circuit illustrated in Figure 4.

![NiMH Battery Discharge Curve](image)

**Figure 3: NiMH Battery Discharge Curve**

![Low-level Battery Indicator Circuit](image)

**Figure 4: Low-level Battery Indicator Circuit**

The handheld control box was first designed to be in a T-shape as shown in Figure 5. This preliminary design allowed for direct sight of the buttons and display. However, the unit was ineffective because all of the buttons were pressed by the thumb. The improved final design shown in Figure 6 is more ergonomic; each of the four buttons is pressed by the four individual fingers of the right hand. Also, an adjustable hook-and-
loop strap is utilized so the unit may be held effortlessly. A hand strap pad was added for extra comfort.

![Figure 5: T-shaped Handheld](image1)

![Figure 6: Ergonomic Handheld](image2)

The initial design required that the lid and batteries be removed from the power supply box in order to be recharged. This was inconvenient for the user and involved removing screws that would eventually strip the plastic threading. This problem was resolved by developing an external battery recharge circuit and mounting the eight D-cell batteries to the lid of the power supply box. Two female plugs extend from the charger and plug into the male jacks on the power supply box. This enables the batteries to be charged four at a time without removing the batteries or lid. The charger and power supply box can be seen in Figure 7 and Figure 8 respectively.
Two cables were made using Ethernet cable and centronic connectors. The cables were used to connect the stepper motor and the hand held device to the power supply box. The cables were color coded to provide proper connections. An example of one of the cables is shown in Figure 9.

The microprocessor placement was also changed from the original mounting inside of the power box. The orientation was altered because of limited clearance between the board and lid. This new placement of the processor allows the serial cable to be easily connected for reprogramming purposes.

The initial software design consisted of two modes: Measure Mode and Step Mode. This meant the camera had to be rotated by hand to set up for these modes. In the revised design solution, Free Rotate Mode was added so the user could position the camera electronically.
**OPERATION OF SYSTEM**

The Motorized Panorama Head provides the photographer with a friendly user-interface that allows the user to create an optimal panoramic photograph. Appropriate information from the microprocessor is sent to the display unit to help the photographer control the panorama head. Three different modes are used in the system operation: Free Rotate Mode, Measure Mode, and Step Mode. The flow chart in Figure 10 shows the order in which these modes are executed. After the Motorized Panorama Head is turned on and initialized, it first enters Free Rotate Mode.

![Flow Chart](image)

*Figure 10: Operation Modes for Motorized Panorama Head*

Free Rotate Mode allows the user to freely rotate the camera clockwise and counterclockwise. There are two instances in the operation of the system where this mode is needed. The first Free Rotate Mode occurs before Measure Mode, allowing the photographer to adjust the camera to a starting point before advancing to Measure Mode. Figure 11 shows the display viewed by the photographer while in Free Rotate Mode. The display contains two fields of information: the current mode and instructions to the user.
Measure Mode consists of the user specifying the desired step size angle. While in this mode, the user measures the horizontal field of view from left to right (rotating the camera clockwise). The first step must be clockwise to avoid measuring a negative angle. CW and CCW buttons located on the keypad are used to rotate the camera. The display in Measure Mode is shown in Figure 12. Information shown in the display includes the number of degrees rotated and instructions to the user. When the user is satisfied with the measurement made, ETR is pressed.

After the horizontal camera view angle is measured, the system enters Free Rotate Mode for the second time. This Free Rotate Mode allows the photographer to select the ideal starting point for the series of photographs.

Step Mode is the final mode in the system operation of the Motorized Panorama Head. Step Mode consists of performing two operations: waiting for the photograph to
be taken, and stepping the specified number of degrees. These two operations are performed until the camera has made a complete 360 degree rotation or the user exits the mode by pressing \textit{RST} or \textit{CCW} and \textit{ETR} simultaneously. Valuable information is provided by the display unit. Figure 13 shows a sample view of the information displayed to the user. The lower left corner of the display shows the number of the picture being taken and how many pictures can be taken in a complete revolution. The other corner displays how many degrees have been stepped throughout step mode.

![Figure 13: Operation LCD Display in Step Mode](image)

After the user has finished taking pictures, the opportunity is given to use the same step angle or to generate a new step angle to take more pictures. If the same step angle is used, the processor will return to the Free Rotate Mode located before Step Mode; otherwise, the processor will return to the Free Rotate Mode before Measure Mode. A description of the subroutines developed for the operation of the system can be viewed in Appendix C.

\textbf{TEST RESULTS}

\textbf{Software Tests}

Throughout the development of the software, fail-safe tests were performed to ensure correct operation of the system. These tests consisted of procedures that checked the functionality of the system when unexpected data was entered. Throughout the design process changes were made in the code after completing fail-safe tests. One of these changes was the combination of buttons used in Step Mode to advance to the end of
the program without rotating a full 360 degrees. Initially, the $CW$ and $CCW$ buttons were pressed to exit Step Mode. This combination was changed to $CCW$ and $ETR$ after performing tests on the system operation. The tests showed that it was easy for the user to accidentally press both $CW$ and $CCW$ because they were located right next to each other on the keypad. Another change to the code was adding a larger delay time in between Measure Mode and Free Rotate Mode. The larger delay time would make sure that the user didn’t accidentally hold ETR too long and skip Free Rotate Mode.

A formal collection of fail-safe tests were completed on April 29, 2003 and can be viewed in the table, “Fail-Safe Tests Performed on Software of Microprocessor”, which is located in Appendix C. No errors were found after completing these fail-safe tests.

**Field Tests**

Two different field tests were performed on the Motorized Panorama Head prototype. The first field test, performed on April 2, involved taking the prototype out to the middle of campus and testing the functionality of the panorama head. In this test, a series of photographs were taken to produce a 360 degree panoramic photograph. The results collected from this test demonstrated that the mechanical part of the prototype needed adjustments.

The problem encountered during this field test was the camera not being able to complete a full 360 degree revolution. This was caused by a loose connection between the custom made shaft and the shaft of the stepper motor. The set screw used to keep these two shafts tightly connected would repeatedly back out. To solve this problem, a drop of Loc-Tite was used on the set screw to keep it firmly in place. No more problems have been encountered after this adjustment was made.

Next, the Motorized Panorama Head was taken out to the same location for another panoramic photograph test. This test was a success. A complete panoramic photograph was taken with the optimal 50 percent overlap of each individual picture. The step size used for this panorama was 14 degrees; therefore, 26 pictures were taken for the full revolution.

A second field test was used to verify the accuracy of rotating the Motorized Panorama Head a full 360 degrees using different step angle sizes. This test was
performed by attaching a laser pointer to the head mount. The laser projected on a wall approximately 90 ft away and this point was marked. Step sizes of 1, 10, 45, and 90 degrees were used to rotate the head a full 360 degrees. In the worst case results, the error was calculated to be 0.28 degrees.

Another test was to verify the error in a one degree step. This test was performed by calculating the distance between two points with a one degree step. These calculations indicate that a point located 90 feet away would move 19 inches. Test results gathered were questionable and the test needs to be repeated.

**Battery Life Test**

There were two tests performed for the life of the battery pack: actual battery life and the system battery life. The current for the system without backlighting was measured to be 0.60 A, and the current for the system with backlighting was 0.62 A. Table 1 shows the calculations for the battery life of the measured system current when the backlighting was on and off.

<table>
<thead>
<tr>
<th>Table 1: Calculated Battery Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlighting</td>
</tr>
<tr>
<td>Current</td>
</tr>
<tr>
<td>Battery Life</td>
</tr>
</tbody>
</table>

The actual battery pack life was found to exceed the calculated 13 hours. Since the low-level battery indicator was designed to illuminate at approximately 80 percent of the actual battery life, the system battery life is reduced. The system battery life was calculated to be 10.4 hours. These results were satisfactory for the system. Testing showed that the system operated for approximately 10 hours before the low-level battery indicator was activated.

**PROJECT MANAGEMENT**
Many factors played a role in the success of the project. Leadership, teamwork, time management, and proper documentation are the key points to the project success.

**Leadership**

One student was given the position of project manager, but every member of the group exercised leadership qualities. Each member of the group was responsible for a specialized area of the project. This enabled the group to expedite the construction of the prototype. Another important factor for having each individual work in their specialized area was that this ensured good workmanship. The project manager was the underlying authority for the project. He was in charge of the following tasks: assigned tasks for the group to carry out, time schedules that had to be met, and documented the progress of the group. The group would work together whenever the project manager called short meetings or when it was necessary for everyone to contribute to a certain task.

**Teamwork**

The group worked as a team throughout the entire year. Many factors contributed to the group working as a team. First, weekly meetings were conducted at every opportunity. They enabled the team to stay up to date, on task, and point out any problems that might have been discovered over the past week. This helped the group to overcome problems as quickly as they arose. Second, if an individual in the group discovered a problem during any portion of the design sequence, the other members of the group could assist him. By doing this, the time spent troubleshooting was drastically reduced. Next, the group utilized a daily journal that documented the group’s progress. This enabled others to come in at different times during the day, skim journal entries, and continue to work on the project. Finally, great preparation, planning, and organizational skills were essential in writing effective presentations and reports.

**Time Management**

One of the most important tasks for the project manager was to keep the project progressing in a timely fashion. Since the project had to be completed by the end of the year, tracking deadlines were crucial. Weekly progress reports provided the group with a
very structured time schedule. Goals were introduced in the reports and progress was monitored on a weekly basis. A Gantt Chart of the entire project can be viewed in Appendix D. The total man hours devoted to the project were also documented and can be seen in Appendix E.

**Documentation**

Documentation was the key to success. During the meetings, the secretary documented what was discussed so that the group knew where to proceed for the next week. The secretary then typed up the meeting notes and passed them on to the project manager. From there, the project manager used these meeting notes to formulate a report for the upcoming meetings. The progress reports included such things as creating agendas for discussion, the progress of the group, and kept a record of the hours contributed by each member in the group. Examples of a progress report can be found in Appendix F. The group also kept a journal where all documentation was kept. Such documents include complete system schematics, preliminary and final wiring documents, PCB layouts, spec sheets, design proposal, and other documents created during the design process.

The schematics contributed immensely during the implementation phase when the system was torn down and rewired. These documents were viewed time and time again. Another document that was useful was the Wiring Instructions Document. This document was prepared by the project manager to guide the group when the system was to be enclosed in the boxes. It also contains information on the pin-outs of the connectors. The Wiring Instructions Document can be seen in Appendix G.

A user’s manual was written for the purpose of explaining the picture-taking operations. It also contains information including: parts checklist, assembly, details of the two boxes, recharging the batteries, and other features of the Motorized Panorama Head. The user’s manual can be seen in Appendix H.

Cost was one of the constraints that the project revolved around. A thorough cost analysis of the project was performed to acquire an idea of the cost for the construction of the prototype. A detailed parts list and pie chart express the total cost of the prototype and can be viewed in Appendix I.
**FUTURE PLANS**

A couple improvements that could be made to the prototype are smaller batteries and better manufacturing of the head mount. Smaller batteries would be sufficient to provide power for the system. The D-Cell batteries chosen for the prototype run the unit in excess of ten hours. Smaller batteries would reduce the weight and charging time, but still provide enough power to run the unit for a reasonable length of time.

The manufacturing quality of the head mount was sufficient for the prototype. For mass production, better materials, facilities, and experience would greatly increase the quality of the unit.

There is a possibility of acquiring a patent for the Motorized Panorama Head in the future. To date, research indicates that there are no patents in the motorized panoramic equipment area. Further research will be done.

**CONCLUSION**

A Motorized Panorama Head prototype meeting the specified criteria in the problem statement was successfully developed. Initially, a block diagram was created to layout the design of the system. Next, identifying constraints enabled the selection of optimal components for each section of the block diagram. Once each component was obtained, the construction of the prototype began. Project management and proper documentation ensured forward progress and guaranteed all deadlines were met. Throughout the construction of the prototype, several enhancements were implemented into the original design. Once completed, testing and revisions were started on the working prototype. Data was collected from field tests and used to verify that its operation met all stated criteria.
**Glossary**

**Angle of View (Horizontal Field of View):**

The width of the area the camera lens can see; measured in degrees [7].

**Backlighting:**

Illumination of the display from behind.

**Data Stream:**

A flow of data from one place to another [8].

**Head Mount:**

The mechanical device that houses the motor and is attached between the tripod and camera.

**Measure Mode:**

The device begins in this mode in which the user physically revolves the camera about the total desired field of view for the picture.

**Panorama Head:**

An attachment connected between the tripod and camera that provides accurate, repeatable angles with the goal of reducing the amount of work you have to do in stitching a panorama together [9].

**Parallel Interface:**

Side by side. For example, a parallel interface can transmit eight bits (a whole byte) at one time, over eight parallel lines [8].

**Serial Interface:**

One at a time. In serial transmissions, one bit at a time is sent over the serial line [8].

**Step Mode:**

Once use of the Measure Mode is completed, the user may enter this mode by pressing a button. This mode steps the motor through step sizes selected in Measure Mode.

**Step Size:**

The amount of camera rotation (in degrees) from one picture-taking position to the next.