Kinematic Mapping System

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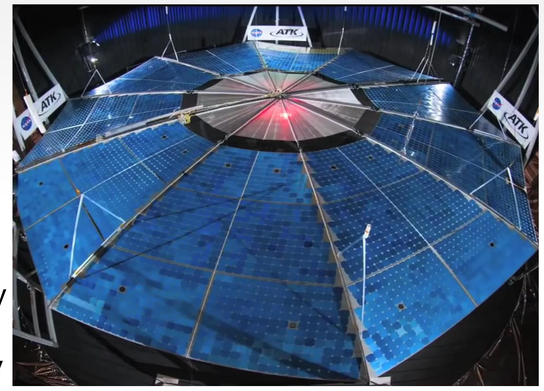
Background

This project is designed to assist Orbital ATK in evaluating the performance of their deployable structures by tracking their motion. Currently this is done using visual inspection.

Overview

This system records the motion of markers attached to the structures using a conventional camera, and then uses software to output the positions of the markers.

This software system isolates the potential markers using color, and refines that output with marker size elimination.



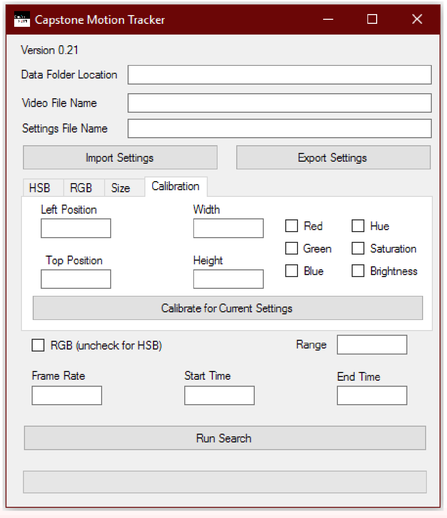
Our project was designed to be:

- Simple to use
- Accurate

It is designed to adapt with any:

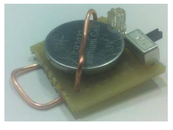
- Marker Type
- Array Geometry
- Array Size
- Camera Quality

Key Components



User Interface

The interface is simple, yet effective at showing what data is needed to properly analyze the data.



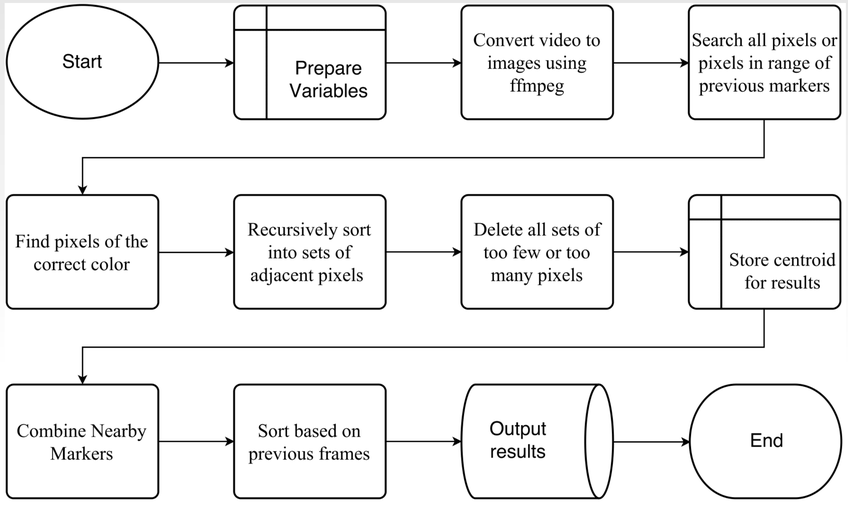
Active Marker

Active markers are composed of an LED, battery, and a resistor.

Program Flowchart

The program is written in C#, and Microsoft's Visual Studios, and uses ffmpeg to decompose video, allowing it to work with almost any video format in one third real time.

The program filters out noise using color ranges, in either the RGB or HSB spectrum, marker size elimination, and positional elimination, which keeps track of where the previous point was, in order to sort the output by marker.



Not shown are the included tools for aiding in calibration. These allow the user to show color values directly, or statistics on the distribution of color values in any or all of any image.

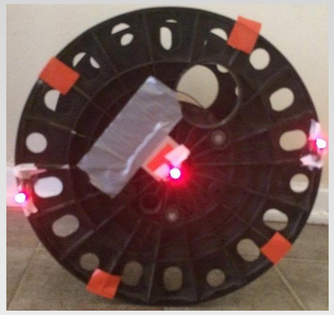
Benchmarks

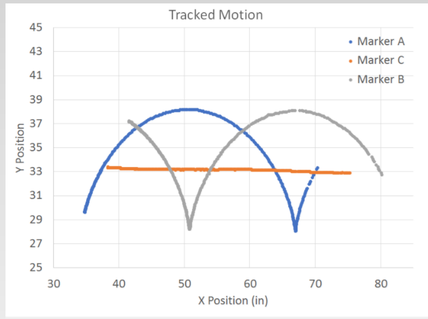
We compared numerous other technologies, in order to find the best technology to meet our benchmarks.

Technology	Wi-fi	Bluetooth	Radar	RFID	Magnetic sensing	Target Spec	Rapid Point
Max Range	10 m	10 m	1 m	10 m	0.66 m	10 m	N/A
Accuracy at 0.5 m	±5 m	±1 m	±1 m	±1 m	±0.0014 m	± 0.1 m	± 0.089 m
Sensor Size	0.31 in^3	3.07 in^3	N/A	0.1 in^3	0.5 in^3	1 in^3	N/A
Sampling Rate	1 Hz	10 Hz	1000 Hz	0.1 Hz	40 Hz	120 Hz	60 Hz

Accelerometers are not shown, because they can not reliably track position at all, due to drift in integration methods.

Accuracy using Cycloid Test





- ± 0.089 inch average deviation from Cycloid model
- Test was performed at a range of 105 inches
- Test was performed at a frequency of 60 Hz

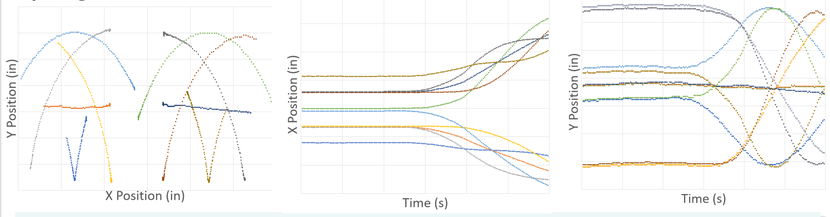
Usability Test

This test was a preliminary test to highlight areas for improvement. A standard usability survey was taken as well, and our system scored 67.5, which compares with an industry average of 68.

- Can the ATK technicians successfully perform each procedure without assistance?
- Some of the details, but a few did need extra verbal explanation.
- How much assistance is needed?
- Not too much. It takes time to read thru and understand everything.
- Which steps take the longest?
- The calibration took the longest.
- Why did those steps take the longest?
- Understanding the function of each button and performing the operations in the correct order.

Multiple Marker Test

This test used points tracked on two wheels to prove our program could track at least up to 10 points at once.



Conclusion

Our project has achieved the desired accuracy while staying well under budget. The program will aid Orbital ATK in analyzing its various arrays: it is easily adaptable to any camera system or marker type, and it includes in-depth calibration routines to suit any kinematic mapping needs.

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