Projector Alignment for Science On a Sphere® (SOS) Using an iPhone, iPod Touch, or iPad

User Manual

Version 5.1+

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sos.noaa.gov

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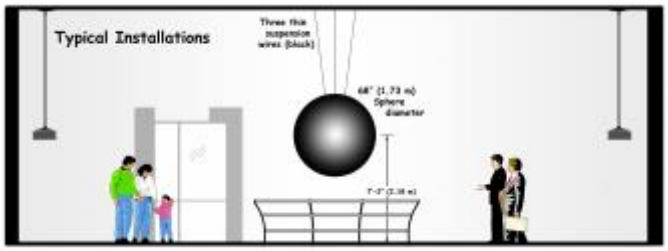
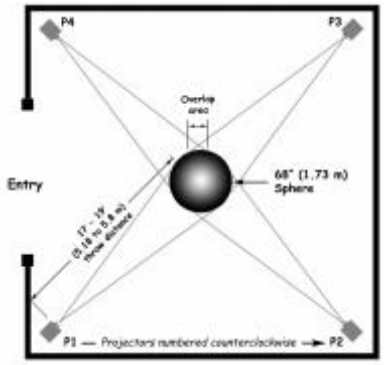
SECTION I: SETUP

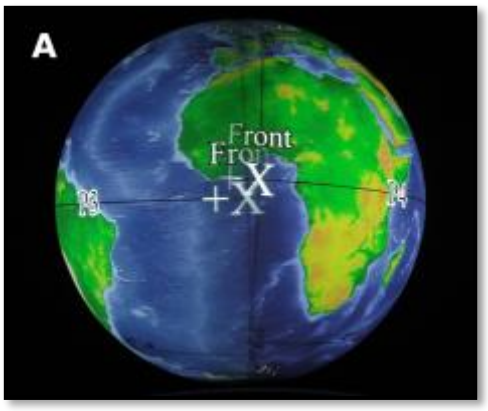
What is Projector Alignment?

SOS is a room-sized display system that uses 4 projectors to display planetary datasets onto a 6 foot diameter sphere. The projectors are located about 17 feet away from the center of the sphere and are mounted approximately 90 degrees apart from each other. Each projector displays a portion of a dataset (which is either an image or a video) onto its quadrant of the sphere.

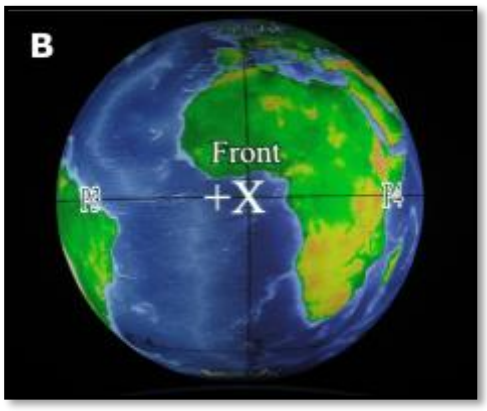




Light from adjacent projectors overlap and create edges in these overlap regions (also called blend regions). This causes the appearance of disjoint images in the areas of overlap. Projector alignment is the process that allows a dataset to be displayed by 4 projectors such that the dataset appears as one continuous image wrapped around the sphere, rather than 4 disjoint images.



[A] shows the overlap region between 2 unaligned projectors; the 2 images look disjoint.



[B] shows the overlap region between 2 aligned projectors; the 2 images look continuous.

Requirements

NOTE: In SOS version 4.3, a new experimental Automated Alignment capability was introduced that uses cameras and computer vision algorithms to automatically align the sphere. If your site is interested in this capability, please see the Automated Alignment section at the end of this manual for all requirements. The rest of this manual describes the steps used to complete a normal manual alignment of the projectors.

If this is the first time you are doing alignment, you will need anywhere from 1 to 2 hours to complete the alignment process. For first time users, it takes some practice, so be patient. If you have done alignment before, or if the alignment is just being tweaked, the process may take anywhere from 15 minutes to 1 hour to complete, depending on what point in the process you are starting at.

To perform projector alignment for an SOS installation, you need to have access to the main SOS computer. (For sites that are still using the 5-computer system, you will only need access to the main SOS NC computer.) In order for alignment results to be saved, you must be logged in as user "sos".

You need to have an iPhone, iPod Touch, or an iPad installed with a copy of the "SOS Remote". This app is available for free download from Apple's App store. You will need Wi-Fi access to connect your mobile device to the SOS computer.

NOTE: The iPhone is used as an example to follow along with throughout this manual. However, all the instructions are the same for the iPod Touch and the iPad. The Automated Alignment interface is only included in the iPad app.

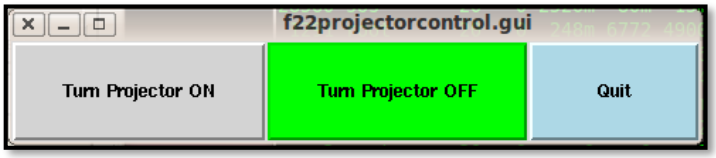
STEP 1: Turn On Projectors

"ProjectorControl.gui" is an application that allows you to easily switch your projectors ON or OFF at the click of a button. This application is typically set up on your SOS computer by the SOS Team during installation.

If this application is not already running on your SOS computer's Desktop, double click the "Projector Control" icon located on the Desktop. Then, click the "Turn Projectors ON" button.

If this application was not installed at your site, turn on each projector by using the projector's remote control.

NOTE: It is recommended that the projectors are on for about 20 minutes before starting alignment.



STEP 2: Set Projector Settings

NOTE: In most cases, you can skip this step, as the SOS Team would have adjusted your projector settings during installation. However, if a projector's settings are accidentally changed, or if a new projector is swapped in for an old one, some settings on the projector may need to be modified.

Lamp Mode: If a room is reasonably dark, use the projector's lower lamp mode setting (if this feature is available). If the room is bright, set the projector to a higher lamp mode setting for greater light output. In general, all projectors should have the same lamp mode setting so that one projector is not brighter or darker than the others.

Lens Shift: If your projector has the option for vertical lens shift, shift the lens down to its lowest point. This is typically the standard point at which a projected image shoots straight out of the projector without any vertical shift. If your projector has horizontal and/or diagonal shift, keep these shifts at their default settings.

Keystone Correction: If your projector is mounted such that it is tilting up or down instead of mostly straight, you may have to use the projector's keystone correction feature to make the projected image more rectangular. For most sites, however, the use of keystone correction is avoided.

Resolution: The projector's resolution should be set to its native resolution. Many projectors offer a higher resolution option that is greater than the native resolution. Regardless, you still need to use the projector's native resolution.

Zoom and Focus: After the lens shift has been adjusted, adjust the projector's zoom (either manually from the projector's lens or via the projector's remote if this option is available). To figure out how far to zoom in or out, first open the Red Ball onto the sphere (see the Red Ball Alignment section). The Red Ball should be fairly centered on the sphere due to physical projector placement. Then, adjust the zoom so that the Red Ball overshoots onto the wall behind the sphere only slightly. Finally, focus the image by looking at the center of the sphere near the equator and using the focus adjustment on the projector or projector's remote.

STEP 3: Edit the SOS Configuration File

NOTE: In most cases, you can skip this step, as the SOS Team would have set up your SOS configuration file during installation. However, if a new projector is swapped in for an old one, or a projector location and/or mount has been changed, or the sphere location has been shifted, some settings in the SOS configuration file may need to be altered.

(A) Measure the height (in inches) from the ground to the sphere's equator. Write this value down.

(B) For each projector, measure the height (in inches) from the ground to the center of the projector's lens. Write each value down.

(C) For each projector, measure the distance (in inches) from the center of the projector's lens to the center of the sphere. Write each value down.

(D) Log on to the main SOS computer as the user "sos". The sos account is set up with administrative privileges and is necessary for editing alignment files. The sos account password will be what was provided to you during installation.

(E) Open the config file: "sos_stream_control.config". This file is located in the directory "/home/sos/".

(F) Modify the appropriate values in the config file to match what you wrote down in parts **(A)**, **(B)**, and **(C)**.

(G) Save the config file and then close the file.

STEP 4: Start the SOS Application on the SOS Computer

In order to perform projector alignment, the main SOS application, called "SOS Stream GUI", must be open and running on your SOS computer. If it is not running, double click on the "Start SOS" icon located on the SOS computer's Desktop to launch the application.

NOTE: If the SOS application was already running on your SOS computer but you had to edit the SOS configuration file as detailed in STEP 3, then close the SOS application and restart it.

STEP 5: Open the Alignment Interface on the iPhone

To open the Alignment interface on your iPhone, tap on the "SOS Remote" app icon located on the home screen. Then, tap on the "Settings" tab. Select the "Alignment" option. A warning message will pop up. Select "Yes" to continue. A white grid against a red background will be displayed on the sphere.

STEP 6: Factory Reset

NOTE – PROCEED WITH CAUTION: A Factory Reset will completely reset the alignment of the projectors in your SOS system. This should only be done if the projectors have been physically moved a lot, or if you have replaced most or all of the projectors, or if the alignment is significantly off. Otherwise, skip to the ***next section, "****SECTION* ***II: ALIGNMENT"****.*

To reset the projectors to their default alignment settings, tap on the "Factory Reset" button located on the Alignment page. A warning message will pop up. Select "Yes" to proceed with the Factory Reset.

SECTION II: ALIGNMENT

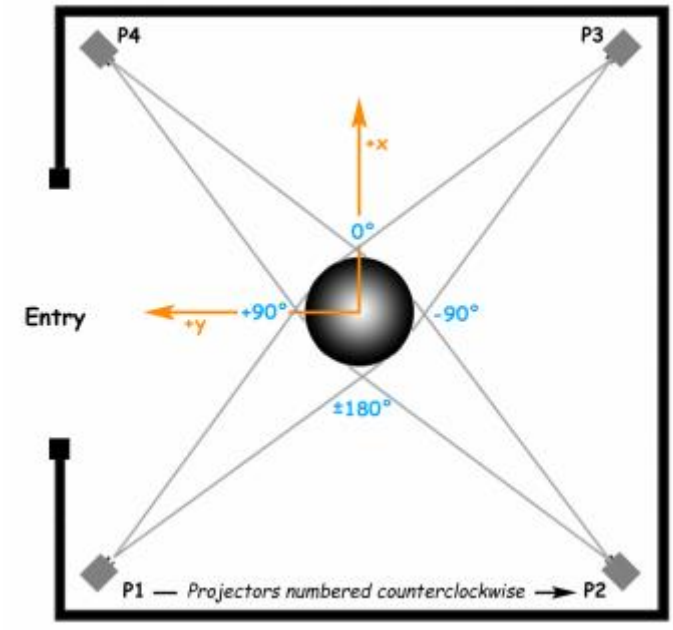
The following 3 steps use the SOS software to bring the projectors into alignment. If this is the first time the projectors are being aligned, or new projectors have been swapped in for old ones, or the alignment is significantly off, start with the next step, "STEP 7: Red Ball Alignment".

However, if the projectors are mostly aligned and just need some tweaking in a few places, you can skip "STEP 7: Red Ball Alignment" and proceed to "STEP 8: Grid Alignment" and/or "STEP 9: Vertex Tweaking".

IMPORTANT: Vertex Tweaking should only be used for fine local adjustments. Do not skip Red Ball Alignment or Grid Alignment if your projectors need more than just fine local adjustments.

NOTE: Please read through the "Alignment Tips" section at the end of this document before beginning for some extra pointers and things to be aware about during alignment.

The closest projector to the SOS computer is typically called projector 1 (P1). The other projectors are named sequentially from 2 to 4 in a counterclockwise direction. See diagram below.



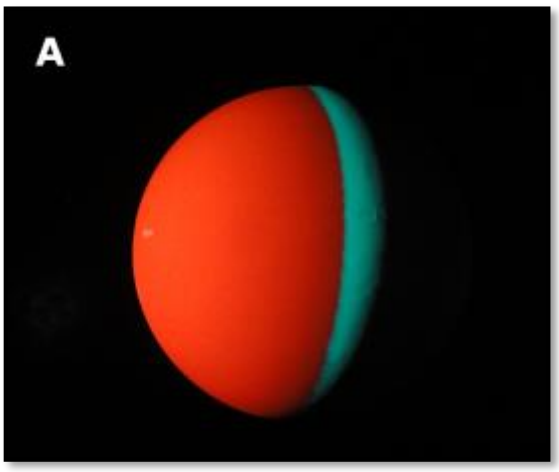
Note that the Entry may be at a different location for your site.

STEP 7: Red Ball Alignment

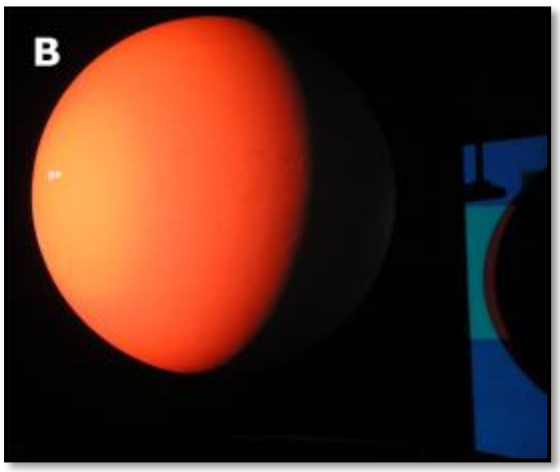
In Red Ball alignment, a red ball against a cyan background is displayed by each projector onto the sphere. The goal of Red Ball alignment is to have the red ball

cover the surface of the sphere in front of the projector and not overshoot the sphere on any side. You also do not want to see any cyan color on the sphere.

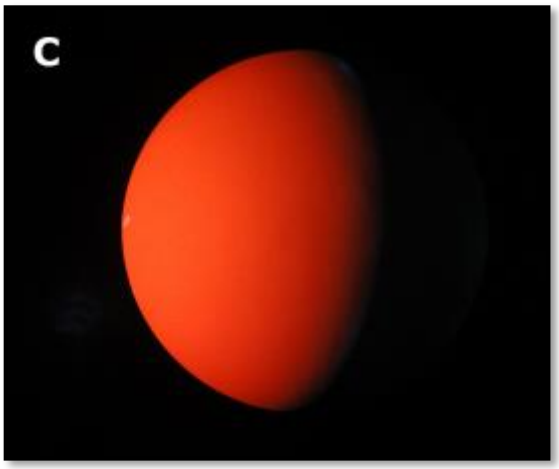
Study the following images before beginning Red Ball alignment.



[A] shows the red ball displayed by 1 projector with the cyan background visible behind it.



[B] shows the red ball displayed by 1 projector with the red overshooting onto the room's wall.



[C] shows the red ball displayed by 1 projector with no cyan background showing and no overshooting off of the sphere.

(A) Tap the "Red Ball" option on the Alignment page to bring up the Red Ball interface. Each projector will display a red ball onto the sphere.

(B) During Red Ball alignment, only one projector should be on at a time. Toggle off all projectors except for projector 1. To do this, tap the "P2" button and then tap the "On/Off" button to toggle projector 2 off. Repeat for projectors 3 and 4. **Now, tap "P1" so that projector 1 is the currently selected projector.**

(C) Use the Translate, Scale, and Rotate controls to adjust the position and size of the red ball of projector 1 so that the red ball covers up the cyan background, and the red ball does not overshoot the sphere on any side.

In this step, it is important to make sure that the red ball is *evenly* positioned on the sphere.

One way to ensure evenness is to first stand in front of the projector. Then, use the Scale controls to evenly scale the red ball down to a small enough size so that you can see cyan color all around the red ball (top, bottom, left, and right). Then, use the Translate controls to center the red ball so that the cyan color is even all around the red ball. To check the evenness of the cyan color, you will have to keep walking from side to side of the red ball as you are adjusting and looking up and down.

Once the red ball is centered, use the controls to expand it until it covers the quadrant of the sphere that you are looking at. As much as possible, you want to prevent the red ball from overshooting onto the room's walls, and you want to cover up most of the cyan. If a tiny bit of cyan color is still showing on one side or another of the sphere, that is okay.

NOTE: As you are making adjustments, you will have to keep going back and forth between the different Translate, Scale, and Rotate (less common) controls because you cannot cover the cyan background with the red ball with just one control. In addition, you can't just stand in front of the projector. You will have to keep moving from side to side of the

sphere to observe the red ball as you are making adjustments.

(D) Tap the “Save” button to save the changes you just made. Note that you can select “Save” at any time during the alignment process, and it is recommended that you save your changes often. Also note that saving will save the changes for all projectors at once, not just the currently selected projector. If changes are made that you don't want to keep, you can revert back to the last time you saved by tapping the “Revert button.

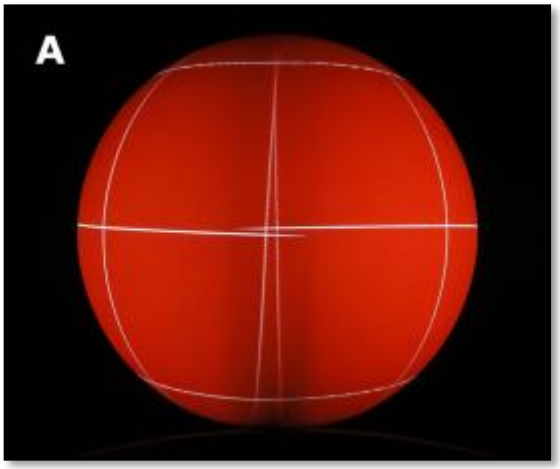
(E) Repeat **(B)**, **(C)**, and **(D)** for projectors 2, 3, and 4.

(F) Tap on the “Done” button to return to the main Alignment page.

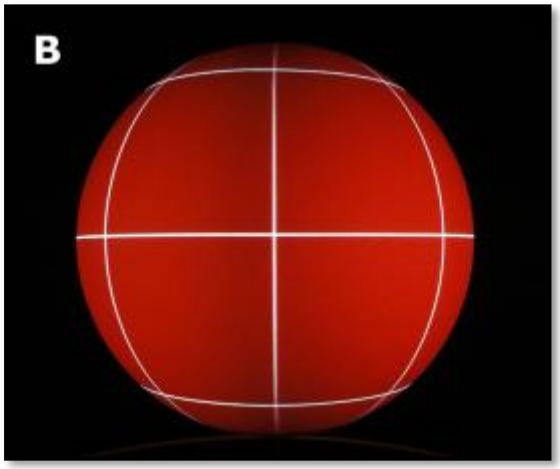
STEP 8: Grid Alignment

In Grid Alignment, a white grid against a red background is displayed by each projector onto the sphere. The goal of Grid alignment is to have the grids line up between all the projectors so that there appears to be one seamless image wrapped around the sphere.

Study the following images before beginning Grid alignment.



[A] shows a view of the grids from 2 projectors that are unaligned in the overlap region.



[B] shows a view of the grids from two projectors that are aligned in the overlap region.

(A) Tap the "Grid" option on the Alignment page to bring up the Grid interface. Each projector will display a white grid against a red background onto the sphere.

NOTE: If this is the first time the sphere is being aligned, or the alignment between some are all projectors is significantly off, it is very useful to use a laser level at this point before proceeding. Ideally, you want horizontal grid lines projected onto the sphere (lines of latitude) to be parallel to the horizontal plane of the room. To help achieve this, set up the laser level so that it projects a level horizontal line on the sphere's equator in front of projector 1. Then, tap the "P1" button to select projector 1. Use ONLY the Rotate controls to rotate the grid of projector 1 so that its horizontal grid lines are parallel to the laser level line. Repeat this procedure for projectors 2, 3, and 4. Then, tap the "Save" button to save your changes.

(B) Tap the "P1" button to select projector 1. In Grid Alignment, you typically want all projectors on most of the time. However, it is often handy to intermittently toggle adjacent projectors on or off in order to see which projectors are causing misalignment in the overlap regions. To toggle a projector on or off, tap on a projector button to select that projector, and then tap the "On/Off" button to toggle it on or off.

(C) Use the Translate, Scale, and Rotate controls to adjust the position and size of the grid displayed by projector 1. You want the grid to line up as closely as possible to the grid lines displayed by the projectors to the left and right of projector 1. **Note that the controls for Grid alignment affect the projector's grid as a whole. You cannot alter specific lines on the grid.**

It is better to move the grid of one projector half way and then move the grid from an adjacent projector half way and have them meet in the middle rather than moving one grid all the way over to the other grid. To do this, you will have to switch over to the adjacent left or right projector in order to adjust their grids slightly, and then switch back to projector 1 to readjust it.

When trying to adjust a grid, it can be confusing as to which projector is

displaying which grid. So again, remember to toggle projectors on/off to be clear on which projector is displaying which grid and which projector's grid lines actually need to be moved.

Remember that even though we may be adjusting multiple projectors (for example, projector 1 plus the adjacent projectors), our intent here is to focus on projector 1 while toggling between the adjacent left and right projectors (projectors 2 and 4 – see diagram at beginning of document for room and projector layout). With this in mind, it is important to just focus on the seams (the overlap regions) between projectors 1 and 2 and projectors 1 and 4.

TIP: In most cases, only the translation and scale controls will be used, and you will not need to use the rotation controls, as rotating will rotate the lines parallel to the equator out of horizontal, which in general we want to avoid.

TIP: When performing Grid Alignment for the first time, adjust the horizontal grid lines of all projectors first (via translating in the left/right directions, and scaling if necessary in the left/right directions), and then go back and adjust the vertical grid lines.

TIP: If the top vertical lines between two overlapping projectors (let's say p1 and p2) are together, but their bottom vertical lines are crisscrossing, though it might not be intuitive, translate both p1 and p2 up by one or more pixels and see if that improves the alignment in the bottom area. Same idea if the top vertical lines are crisscrossing...in this case, translate both p1 and p2 down by one or more pixels.

TIP: At the end of Grid Alignment, if you get to the point where you can't fix one grid without making the adjacent worse, try Vertex Tweaking those areas.

(D) Tap the "Save" button to save the changes you just made. Note that you can select "Save" at any time during the alignment process, and it is recommended that you save your changes often. Also note that saving will save the changes for all projectors at once, not just the currently selected projector. If changes are made that you don't want to keep, you can revert back to the last time you saved by tapping the "Revert button.

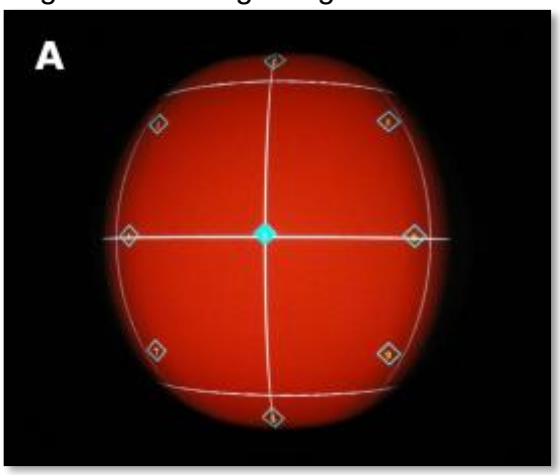
(E) Repeat **(B)**, **(C)**, and **(D)** for projectors 2, 3, and 4.

(F) Tap on the "Done" button to return to the main Alignment page.

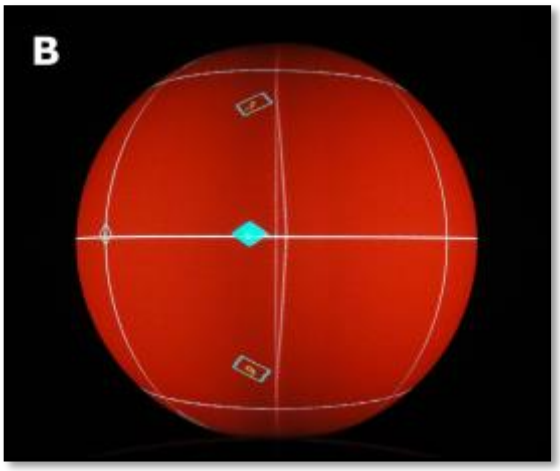
STEP 9: Vertex Tweaking

Once the image is fairly close to being seamless, Vertex Tweaking is the final step used to further perfect the alignment. In Vertex Tweaking, a set of numbered vertices corresponding to specific areas of the grid image are displayed by each projector onto the sphere. The goal of Vertex Tweaking is to fine-tune the alignment near these specific areas.

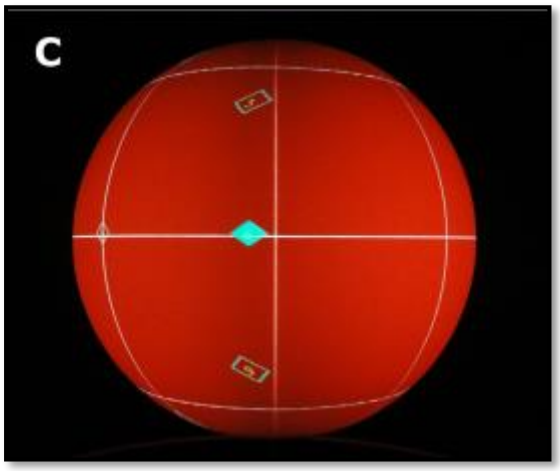
Study the following images before beginning Vertex Tweaking.



[A] shows the set of vertices displayed by 1 projector (the two adjacent projectors have been toggled off).



[B] shows the overlap region between 2 projectors, with the vertices displayed by the projector on the left. A selected vertex (a numbered diamond shape filled in with cyan color) is also shown. The line near this vertex is out of alignment.



[C] After the Vertex Tweaking procedure, the line near the selected vertex is in alignment.

(A) Tap the "Vertex Tweaking" option on the Alignment page to bring up the

Vertex Tweaking interface. Each projector will display a white grid against a red background onto the sphere.

(B) Tap the "P1" button to select projector 1. A set of numbered vertices will be displayed onto the sphere by projector 1. In Vertex Tweaking, you typically want all projectors on most of the time. However, it is often handy to intermittently toggle adjacent projectors on or off in order to see which projectors are causing misalignment in the overlap region. To toggle a projector on or off, tap a projector button to select that projector, and then tap the "On/Off" button to toggle it on or off.

(C) Select a vertex you would like to adjust by tapping on one of the vertex buttons labeled "1" through "9". Use the Translate controls to move the image up, down, left or right. The image will only stretch near the selected number. So for example, if a whole side needs to move left, you need to stretch it by adjusting the top, middle, and bottom vertices to the left.

It is sometimes confusing to figure out which projector is displaying a grid line in the overlap region, so it is helpful to toggle the adjacent projectors on and off to differentiate between the grid lines and to know which projector's grid line actually needs to be moved.

Also, if two lines from two adjacent projectors are separated that shouldn't be, it is better to move each line from each projector half way and have them meet in the middle rather than moving one line from one projector all the way to the other. To do this, you will have to switch over to the adjacent left or right projector, adjust that projector's relevant vertex slightly, and then and then switch back to projector 1 to readjust its relevant vertex.

Remember that even though we may be adjusting multiple projectors (for

example, vertices of projector 1 plus the vertices of the adjacent projectors), our intent here is to focus on projector 1 while toggling between the adjacent left and right projectors (projectors 2 and 4 – see diagram at beginning of document for room and projector layout). With this in mind, it is important to just focus on the seams (the overlap region) between projectors 1 and 2 and projectors 1 and 4.

TIP: Consider starting the process of Vertex Tweaking by adjusting the vertices 4 and 6 first, followed by vertices 1, 3, 7, 9, and finally vertices 2 and 8.

(D) Tap the "Save" button to save the changes you just made. Note that you can select "Save" at any time during the alignment process, and it is recommended that you save your changes often. Also note that saving will save the changes for all projectors at once, not just the currently selected projector. If changes are made that you don't want to keep, you can revert back to the last time you saved by tapping the "Revert button.

(E) Repeat **(C)** and **(D)** for any other vertices you would like to adjust for projector 1.

(F) Repeat **(B)**, **(C)**, **(D),** and **(E)** for projectors 2, 3, and 4.

(G) Tap on the "Done" button to return to the main Alignment page.

(H) This completes the alignment process. Tap the "Settings" back button on the navigation bar of the Alignment page to get back the main Settings page.

ALIGNMENT TIPS

- When adjusting grids in Grid Alignment or Vertex Tweaking modes, if you find that you need to make more than one adjustment (for example, one tap of the translation control), then switch back and forth between adjacent projectors so that the grid lines will eventually "meet in the middle".

- It is recommended that the projectors are on for 15-20 minutes before starting alignment as we have found that the images sometimes move slightly as the projectors warm up.

- It is recommended that you save the alignment several times throughout the alignment process so that if you adjust a projector but immediately decide that you need to revert that adjustment, you will be taken back to the most recently saved alignment that you were satisfied with.

- If your projectors are significantly out of alignment, don't just use Vertex Tweaking to try to fix it. Vertex Tweaking is meant only for fine local adjustments. If you just use Vertex Tweaking for gross alignment, you may begin to see significant image tearing and other artifacts on the sphere. Go through each of the 3 alignment steps (Red Ball, Grid, Vertex Tweaking) in order to fix the alignment.

- If you are checking your alignment every few weeks, and you find that the alignment is only slightly off, often times this indicates that a projector has been slightly moved (maybe due to a projector being bumped, room vibration from large crowds, etc). Try using the Grid alignment interface and only the Translate controls to adjust it. This may be enough to bring the projector back into alignment. In addition, check to make sure the projector mount screws are tight, and that the mount itself is stable and tight.

- After Grid alignment, vertical grid lines should be parallel to each other. If you find that some vertical lines at the top or bottom of the sphere are diverging or crisscrossing in the overlap regions between projectors, this may indicate that the ground to sphere center measurement was not optimally measured (see STEP 3). Re-measure the distance from the ground to the sphere center. If it is indeed accurate, consider adding or subtracting 1 inch from this measurement and then re-entering it into the SOS configuration file as described in STEP 3. Be sure to re-start the main SOS application after making this change. Then, re-run the Grid alignment interface to see if that made a difference.

- If you swap out a new projector for an old projector, you may need to change your computer's "xorg.conf" file so that the computer will know the correct configuration (screen resolution, etc.) for your projector. Please contact sos.gsd@noaa.gov to ask for technical assistance about how to do this.

- The SOS computer automatically backs up alignment files every day. If you want to reset your alignment files to an older backup, open a terminal and run the following command (note that you must be logged on to the SOS computer as the "sos" user to perform this operation):

  cp /shared/sos/site-backup.your-computer-name/date/shared/sos/site-config/site-config/alignment/* /shared/sos/site-config/alignment/

  where **your-computer-name** is the name assigned to your computer and **date** is the timestamp of the alignment files you are interested in restoring (for example: 2012-01-26-00:8:30).

Exit the SOS Stream GUI application on the SOS computer and then restart it in order for the new alignment files to take affect.

AUTOMATED ALIGNMENT

Overview

With the release of SOS version 5.0, we are continuing work on the experimental automated alignment capability. Using cameras and computer vision algorithms, this feature adds a one-step "Auto Align" button to each of the three alignment stages (Red Ball, Grid, and Vertex Tweak). Our experience has been that under good lighting conditions, the automated alignment does an acceptable job by itself. Each step of automated alignment can be further improved through manual adjustments by an experienced person. At this point, automated alignment is intended to provide a good first step in aligning.

The use of automated alignment requires the purchase and installation of additional hardware beyond the basic SOS installation. Costs for the additional hardware should be around or under $2000. For more information about what hardware is required, please contact us at sos.gsd@noaa.gov.

We encourage you to reach out if you want to give this exciting new capability a try at your SOS site!

Limitations

We consider this to be an experimental capability due to limited testing outside of our development environment. We have excellent control of ambient lighting at our SOS facility. Some of the computer vision algorithms can be thrown off by ambient light or by direct light shining on the sphere. Ongoing development should improve the algorithms over time.

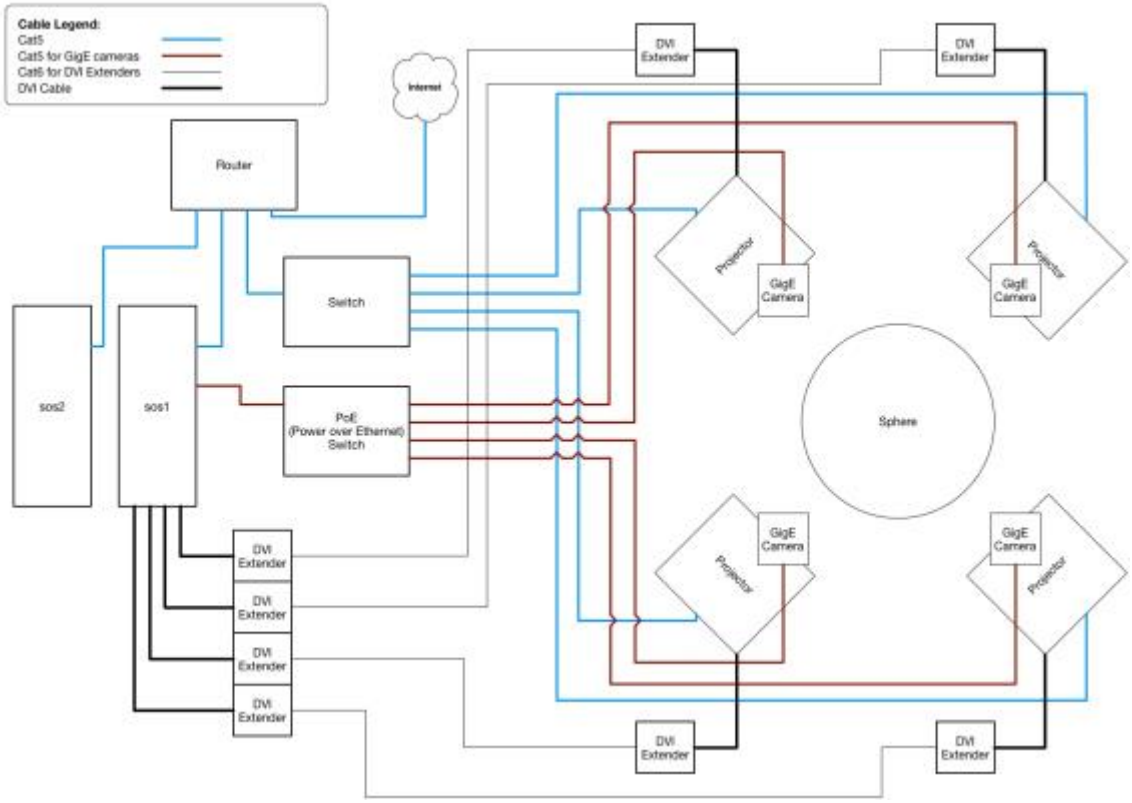
Hardware

We use four Point Grey GigE machine-vision cameras for auto alignment. (One for each SOS projector) Each camera should be mounted as close as reasonable to the lens of the corresponding projector. At our site, each camera is mounted directly on top of the projector. The below images are a good example:

Cat5 Ethernet cabling connects each webcam to the SOS computer. We've tested the cameras on cables as long as 300 feet with good results. At our site,

each computer has one extra Ethernet Card devoted to communicating with the auto alignment cameras. We run one Ethernet cable to a 5 port PoE (Power over Ethernet) networking switch near the projectors. From that switch, we run individual cables to the cameras. The Ethernet cable provides both communication and power to the cameras

A cable diagram for the system looks like the below:

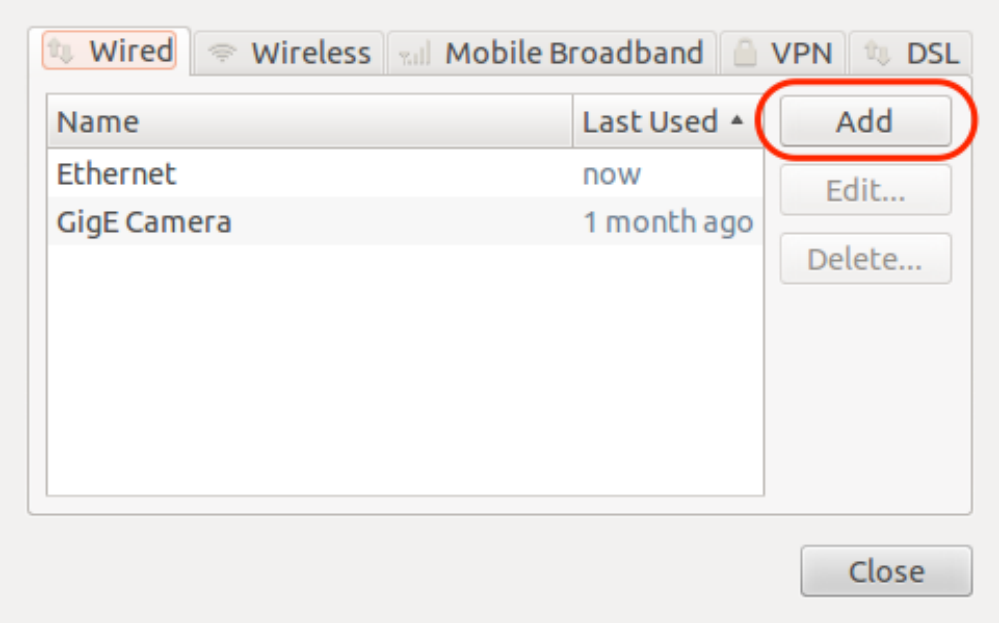


Installation

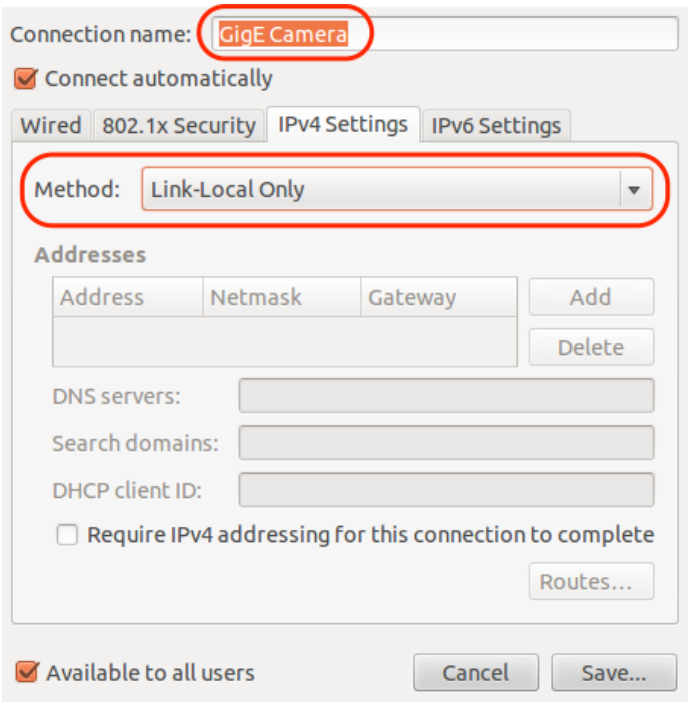
Once the cameras are physically in place you will need to do a few more steps to fully configure them to work with SOS.

First, you'll need to set up a new Ethernet connection for the computer to use. To do so, open the Network Manager and add a new configuration as a "Link Local Address". See the images below:

Find & open the Network Connections Program

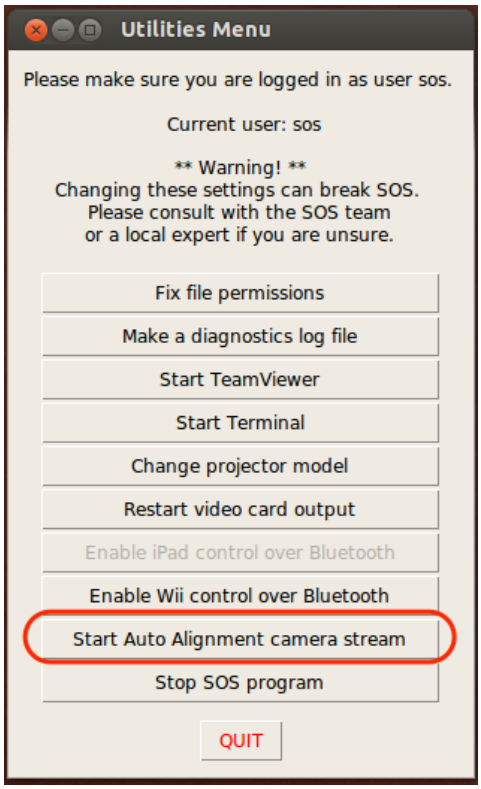


Select "Add" to add a new connection



Name the new connection and change the Method to "Link-Local Only". Then click "Save..."

Second, you will need to adjust the focus on the lens. You may find this easier to do with two people. To start, open the SOS Utilities program and select the "Start Auto Alignment camera stream" option. See the below image:



You should then adjust the focus on the lens using the adjustment screw closest to the camera body until the image is in focus. You may also need to adjust where the camera is pointed so that the sphere is in the frame.

Configuration

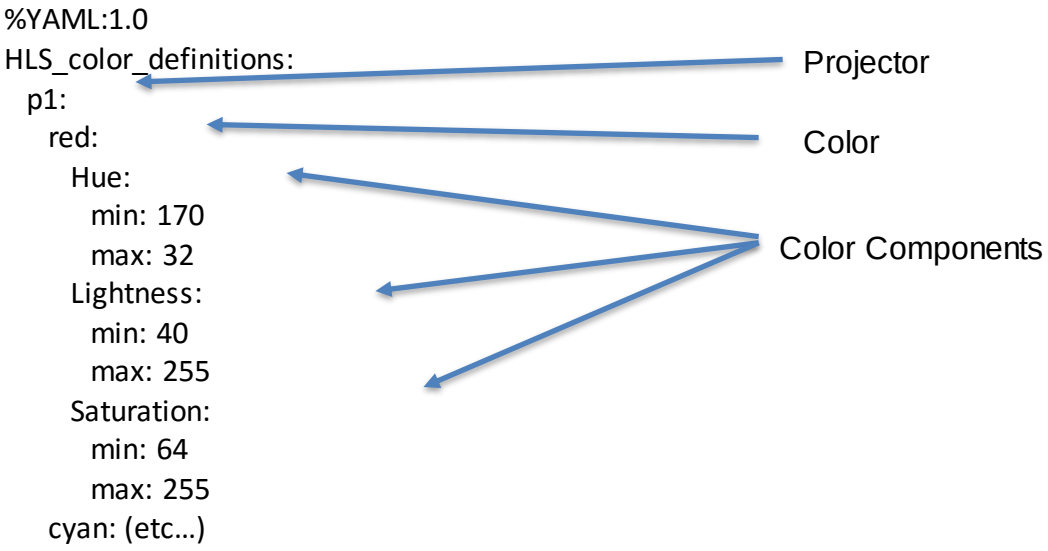
If you have good control over the ambient lighting in your exhibit auto alignment will most likely work out of the box. However, if you have ambient light in your exhibit you may need to edit the color definitions.

New in this version is the ability to specify a color range for each projector. It does require some use of the terminal and you will want to ensure that light conditions will remain similar to the conditions you had when you setup your config file. (The less ambient light, the better) If auto alignment isn't returning satisfactory results and you would like to try modifying the color definitions, you should try the following:

In a terminal, enter:

```
cp /shared/sos/etc/auto_align/default_colors.yaml ~/auto_align_colors.yaml
```

Then, open the auto_align_colors.yaml file in your home directory with a text editor. You will see something like the following:



In the file projectors are defined by "p1, p2, etc…", the color you're editing is defined by the "red" or "cyan" markers. And the color values are defined by the "Hue, Lightness and Saturation" components. Each color component has a minimum and maximum value.

An aside about the color components. Most people are familiar with colors definied by RGB values. Auto Alignment uses colors defined in the HLS color-space. (HLS is also known as HSL) A bit about each value:

- Hue
  - valid numbers are from 0 to 180. Hue is measured in degrees and so values can wrap around 180 back to 0. It represents the base color. (red, yellow, etc…)
- Lightness
  - valid values are from 0 to 255. Lightness does not wrap. Lightness determines if your color has a dark hue or a light hue. (dark red vs light red) 0 is black, 255 is white.
- Saturation
  - valid values are from 0 to 255. Saturation does not wrap. Saturation can be thought of as representing the amount of color. 0 can be thought of as "dull" while 255 is "vibrant" color.

More about the HLS color-space can be found online. Wikipedia's entry provides a good overview. https://en.wikipedia.org/wiki/HSL_and_HSV

Please don't change the formatting of the file, just update the values. If the format is changed, you can always re-copy the default_colors.yaml file and re-enter your custom values.

You will want to update the values in this file based on the information you obtain from the "sampleImage" utility included with SOS. The utility is run on the diagnostic images output by the auto alignment algorithms. The images will be stored in /tmp after running auto alignment. You can run the utility by doing the below in the terminal:

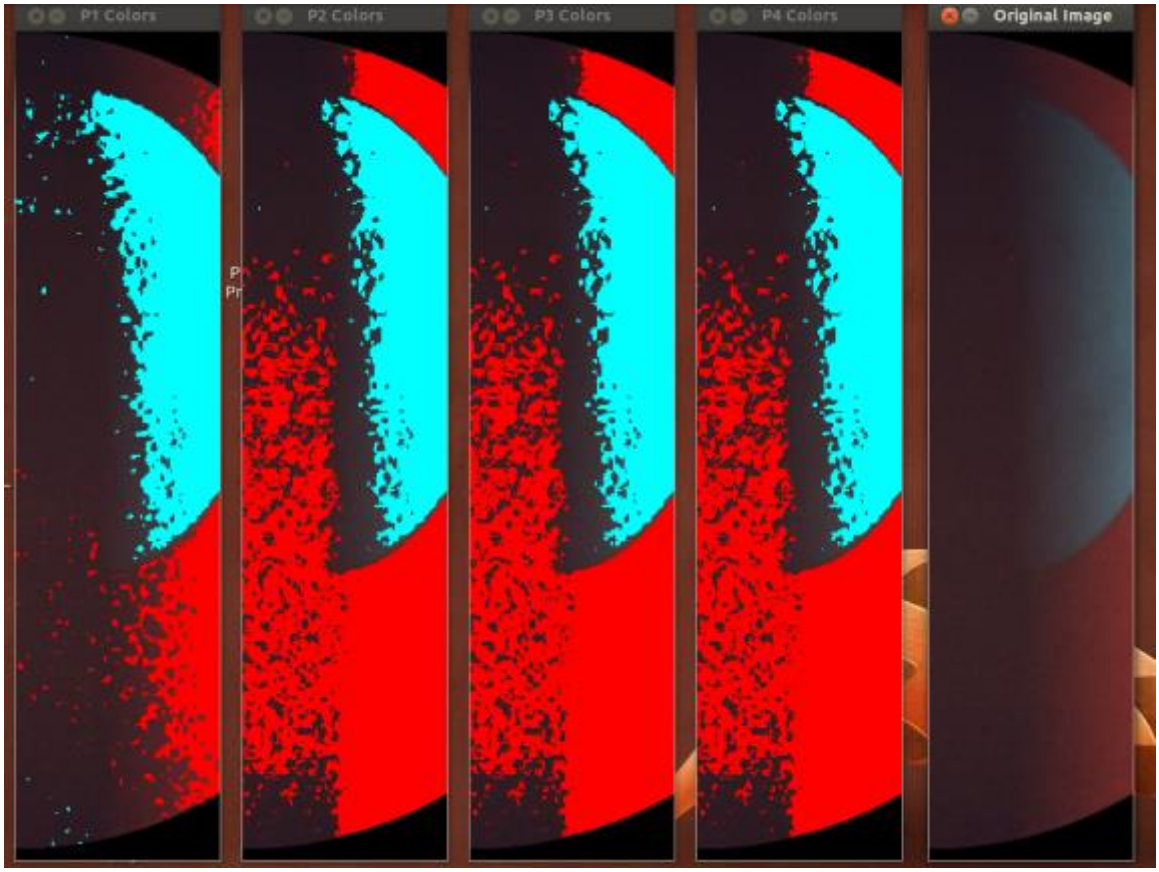
```
/shared/sos/bin/sampleImage </path/to/image>
```

An example:

After running redball alignment, you want to update the colors, so you run:

```
/shared/sos/bin/sampleImage /tmp/imageLeft2.jpg
```

You will then see something like the below:



Four images rendered using the color definitions for each projector (P1 – P4 Colors) along with the Original Image

You will see the original image obtained by the camera along with 4 renderings of that image as the algorithms see it once a projector's color definition is applied. You will really only need to reference one of the images. The numbers in an image's filename correspond to the projector they were taken from. Since this image belongs to projector 2 we will focus on the rendered image labelled "P2 Colors".

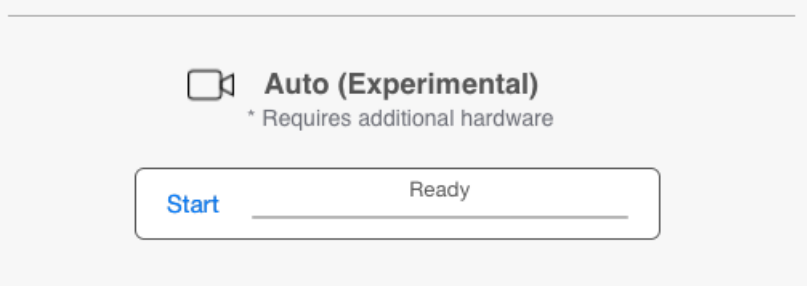
As you can see in the "P2 Colors" image, the camera is finding extra red in the image and is finding less cyan than it should be. You can click on the "Original Image" and the software will print the HLS values for the pixel clicked in the terminal. You can use these values to determine how to change the color definitions in the auto_align_colors.yaml file.

It may take a few tries before you find set of color definitions that work well for your site. We recommend you try this using the redball step. The imageLeftX.jpg and imageRightX.jpg images are what we usually use to tweak our color definitions.

Software

Automatic alignment has been integrated into each of the 3 steps of the Alignment menu of the SOS Remote app. The following section has been added to the bottom of the user interface:

Pressing the Start button will run an automated alignment for the current alignment step. While the automated alignment is running, a progress bar will update as the alignment proceeds. The progress bar is only an approximation, since the time required for each step is not fixed. An automated Red Ball alignment takes approximately 8-10 minutes. Automated alignment for the Grid and Vertex Tweaking steps each typically take 2-4 minutes. While the automated alignment is in progress, the corresponding manual alignment controls are disabled. When the automated alignment completes, the manual alignment controls are available for additional refinement of the results.



As with a manual alignment, the results of the automated alignment are not automatically saved to disk. When the user is satisfied with the alignment, they must press the Save button to permanently save the results to disk. As with a manual alignment, the Revert button will revert the alignment state to the last Saved version.

Diagnostics

Since automated alignment is somewhat experimental, we provide a few diagnostics that might prove useful, perhaps for the curious user or for the benefit of the SOS development team. Each of the three automated alignment steps writes a log file in the soslogs directory below the sos user's home directory. The files are named redballSideAlignment.log, gridAlignment.log, and vertexTweakAlignment.log. From a terminal window you can use the tailf command to watch the alignment progress. For example:

tailf ~/soslogs/redballSideAlignment.log

will show lots of magical numbers that the grid alignment is using in its calculations.

There are also some key image files written to the /tmp directory, which can be viewed with the display command. The files /tmp/CameraN_sphere_loc.jpg (where N is 0-3) show a green circle where the software thinks the sphere is in the corresponding camera's view. The files /tmp/IdentifyCameraN.jpg (where N is 0-3) shows which projector is viewed by each camera. Some additional image files are written to /tmp at key points of the computer vision algorithms.

CONTACT

If you have any questions regarding alignment, please contact:
sos.gsd@noaa.gov

Appendix A – Auto Alignment with Logitech Webcams (Deprecated)

Overview

The auto alignment code still works with the original webcams we recommended. However, due to the webcams' limitations we are focusing our future work on new machine vision cameras. For the time being, we won't break compatibility with the webcams. However, new features may not work for them. We're keeping the old setup instructions here.

With the release of SOS version 4.3, we are introducing a new experimental automated alignment capability. Using cameras and computer vision algorithms, this feature adds a one-step "Auto Align" button to each of the three alignment stages (Red Ball, Grid, and Vertex Tweak). Our experience has been that under good lighting conditions, the automated alignment does an acceptable job by itself. Each step of automated alignment can be further improved through manual adjustments by an experienced person.

The use of automated alignment requires the purchase and installation of additional hardware beyond the basic SOS installation. Four commodity webcams and associated USB wiring are required. For most SOS installations, the additional hardware cost should be well under $1000.

We encourage you to contact us if you want to give this exciting new capability a try at your SOS site!

Limitations

We consider this to be an experimental capability due to a lack of testing outside of our development environment. We have excellent control of ambient lighting at our SOS facility. Some of the computer vision algorithms can be thrown off by bright ambient light or by direct light shining on the sphere. Ongoing development should improve the algorithms over time.

Hardware

We use four Logitech C920 webcams (one for each SOS projector), which are available under $100 each. Each camera should be mounted as close as reasonable to the lens of the corresponding projector. At our site, we just sit each camera directly on top of the projector. The below image is a good example:

USB cabling connects each webcam to the SOS computer. At our site, we run USB extender cables from each camera directly to a USB port on the SOS computer. We have had luck with the IOGEAR GUE2118 36 ft. cables (approximately $30 each), daisy-chaining two to four cables for some of the runs. For sites where the SOS computer is adjacent to the SOS display, this should be adequate. For longer USB runs, a more expensive USB extender solution will be required, with a hub near the projectors to feed the individual cameras.

Installation

When the cameras are connected to the SOS computer, they should be automatically detected by the Ubuntu operating system. This can be verified from a terminal window by typing the command:

ls /dev/video*

The resulting output should show four devices:

/dev/video0 /dev/video1 /dev/video2 /dev/video3

The cameras can be further validated with a linux webcam program known as "cheese." It should already be installed on your SOS computer. But if it is not yet installed, you can install cheese from the command line or the Ubuntu Software Center as user sos.

From the command line it can be installed by typing the command:

sudo apt-get install cheese

From the Ubuntu Software Center it can be installed by searching for “cheese”, selecting the “Cheese Webcam Booth” from the results and clicking “Install”.

Once installed, just run cheese from a terminal window by typing:

cheese

Or from the Desktop launcher by clicking the Ubuntu logo in the upper left hand corner of the desktop and searching for “cheese”. Click the application that appears in the search results to launch the program.

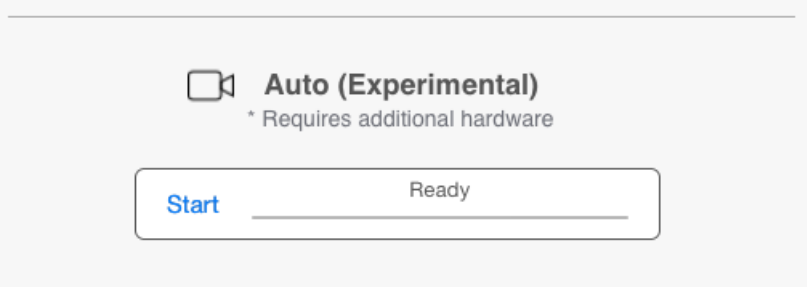
Once launched, cheese will open a window which should show the view from one of your cameras. The specific camera can be selected from the Preferences under the Edit menu. From the Device entry, you should be able to select the view from each of your cameras. Verify that the sphere is visible and roughly centered from the point of view of each of your cameras, and reposition the camera as necessary. These webcams have a wide field of view, so this shouldn’t be difficult.

NOTE: The cameras can’t be shared between programs, so make sure to exit cheese before running an automatic alignment.

Software

Automatic alignment has been integrated into each of the 3 steps of the Alignment menu of the SOS Remote app. The following section has been added to the bottom of the user interface:

Pressing the Start button will run an automated alignment for the current alignment step. While the automated alignment is running, a progress bar will update as the alignment proceeds. The progress bar is only an approximation, since the time required for each step is not fixed. An automated Red Ball alignment takes approximately 8-10 minutes. Automated alignment for the Grid and Vertex Tweaking steps each typically take 2-4 minutes. While the automated alignment is in progress, the corresponding manual alignment controls are disabled. When the automated alignment completes, the manual alignment controls are available for additional refinement of the results.



As with a manual alignment, the results of the automated alignment are not automatically saved to disk. When the user is satisfied with the alignment, they must press the Save button to permanently save the results to disk. As with a manual alignment, the Revert button will revert the alignment state to the last Saved version.

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