

CI-110/120 Plant Canopy Imager

Hardware and Software Manual

Version 5.0.9



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Document Overview

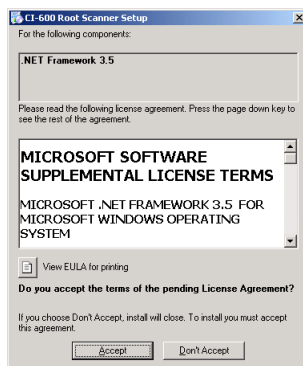
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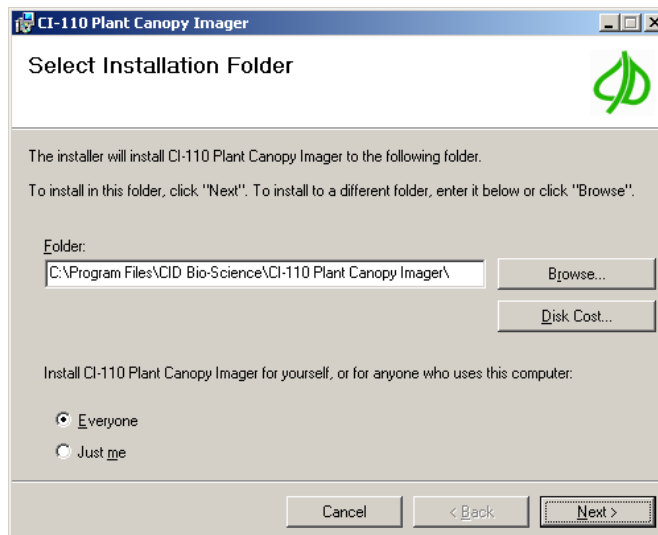
Software Installation

The following steps should be repeated on each computer used with the CI-110/120 Plant Canopy Imager.

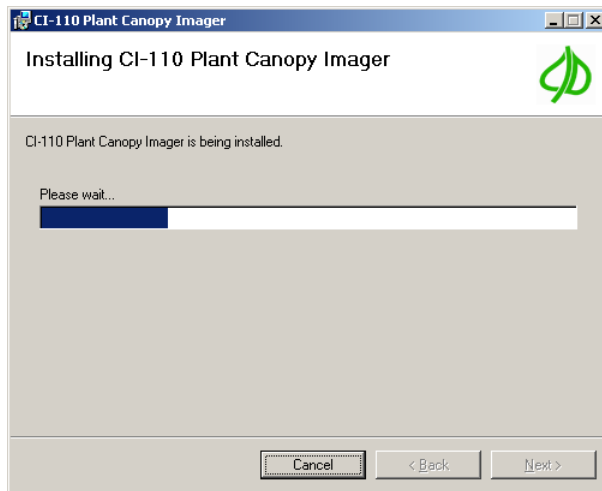
1. Insert the supplied CI-110/120 CD disc in your CD-ROM drive. The setup program will automatically start unless Auto-Run has been disabled in Windows. If this is the case browse the CD-ROM drive and run Setup.exe manually.
2. If version 3.5 of the Microsoft .NET is not installed you will be prompted to accept Microsoft's terms of use before continuing. Click **Accept** to continue.



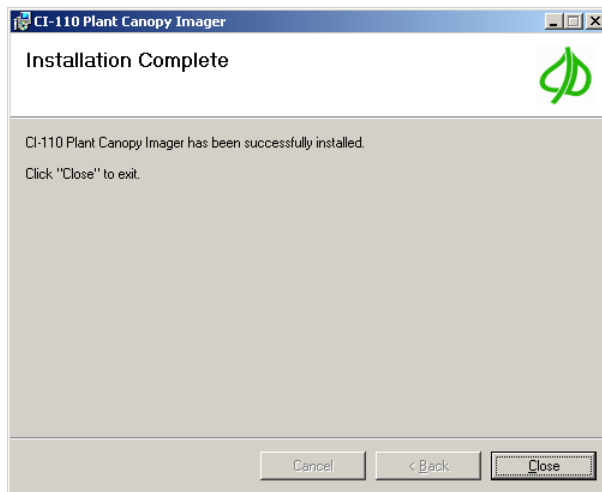
3. You may be prompted to reboot. If prompted, reboot. Setup will continue when the system starts again.
4. The dialog below will appear. Specify the folder to use for this application and click **Next** to continue.



- The installation process will take about 5-10 minutes. Your system may appear to be non-responsive but do not restart the computer during this step.



- The dialog below will appear when setup process is complete. Click **Close** to exit the setup program.



- The CI-110 software has now been installed. Connect the CI-110/120 device via USB. Windows should automatically detect the drivers installed by this setup program. Do not attempt to start the CI-110 software while the driver is installing.
- Windows may change the default sound playback device to the USB audio device in the CI-110. To correct this open the Control Panel, click the Sound icon and change the default playback device to your preferred device.

Hardware Installation

The following steps should be repeated on each computer used with the CI-110/120 Plant Canopy Imager.

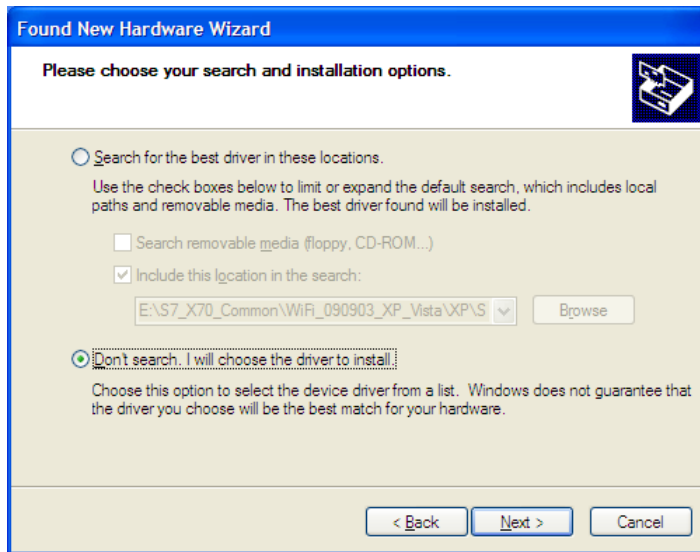
1. Attach the CI-110/CI-120 device using the supplied USB cable.
2. After a few moments a sound should indicate Windows has found a USB device.
3. Windows should display the “**Found New Hardware Wizard**”. Windows may ask you to search Windows Update for a driver. If prompted, choose “**No, not at this time**” and click **Next** to continue.



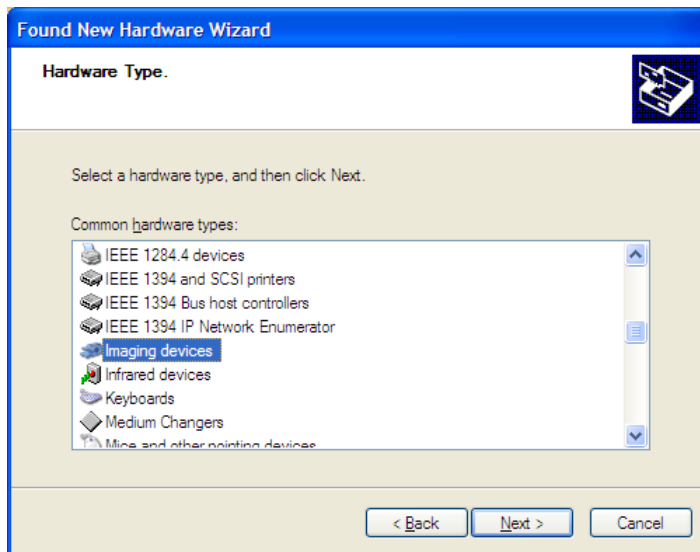
4. You will be asked to install software automatically, or from a specific location. Choose “**Install from a list or specific location (Advanced)**” and click **Next** to continue.



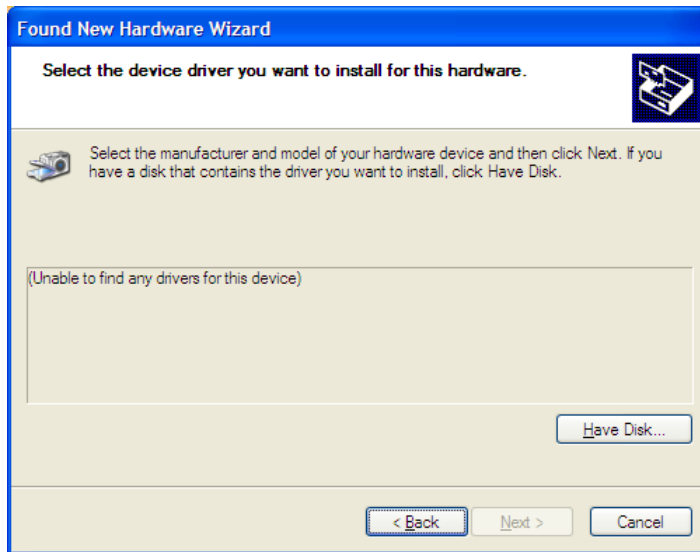
5. Windows will ask again if it should search for your driver. Choose **“Don’t search. I will choose the driver to install.”** And click Next to continue.



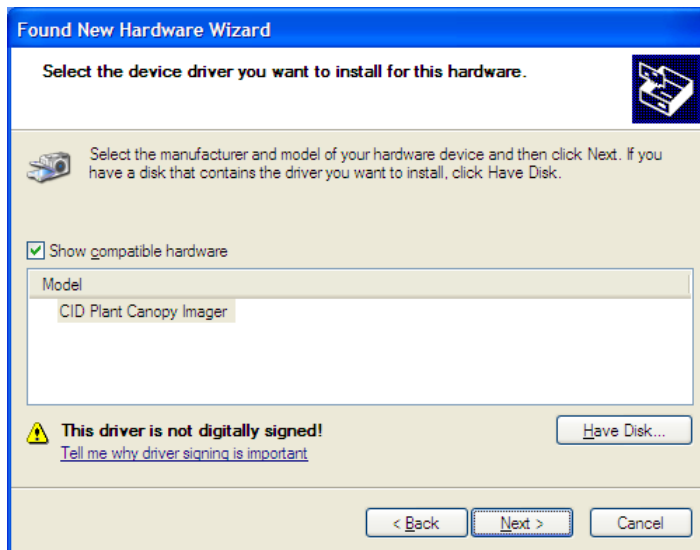
6. You will be prompted for the type of hardware to install. Select **Imaging Devices** and click **Next** to continue.



7. Click **Have Disk...** and type or browse to “**C:\Program Files\CID Bio-Science\Plant Canopy Analysis System\Drivers**” Then click **OK**.



8. Select **CID Plant Canopy Imager** and click **Next** to continue.



9. Windows will warn you that CID's driver has not been signed. Click "**Continue Anyways**"



10. A dialog will appear stating that setup has completed. Click **Finish** to dismiss the dialog.



11. Windows may have changed the default sound playback and recording device while installing the CI-110 / CI-120. To verify Windows is setup properly follow these instructions...
- Open the Control Panel.
 - Open Sound and Audio Devices.
 - Click the Audio tab.
 - If the default playback or recording device is "**2 Channel USB Audio**" change it to another selection in the list (when using the Viliv X70 tablet PC select "**IDT Audio 1**" for both entries.)

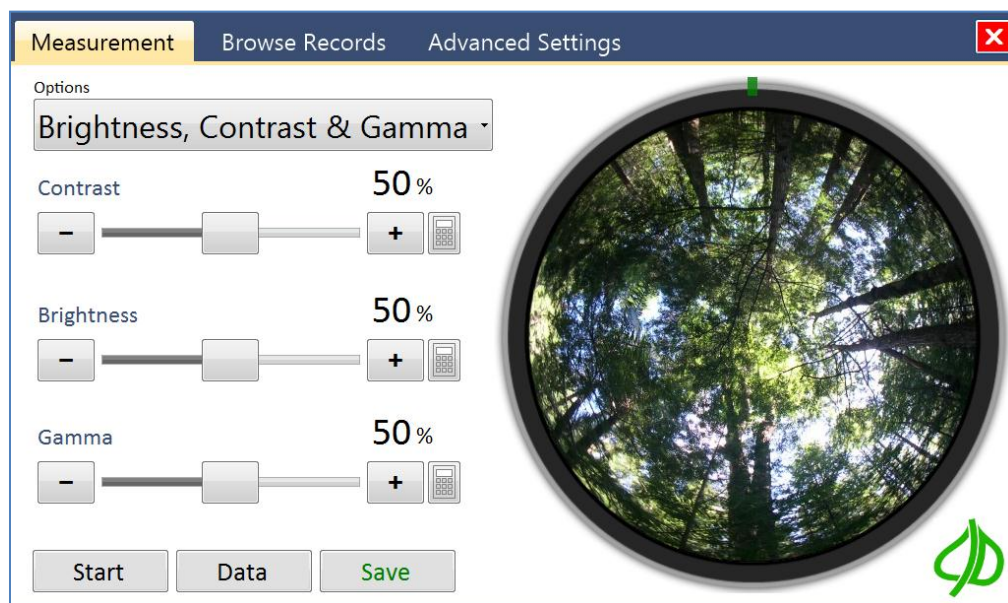
Getting Started

These instructions will walk you through basic operation of the CI-110/120 software. The *Application Tabs* and *Tips* sections that follow will go into more detail on functionality and features.

Starting the application

1. Click on the Windows **Start** button.
2. Go to **Programs** and find the **CID-Bio Science** folder.
3. Select **CI-110 Plant Canopy Imager**.

The dialog below will appear...



Enabling GPS

The CI-110/120 software will automatically record your current GPS position with measurements if a GPS device is connected.

1. Click the **Options** list and select **Location**.
2. Click the **Connect** button.
*The text to the right of the button will change to **Detecting**. The CI-110/120 software will search the system for a GPS device and automatically connect to it. When the status text changes to **Connected** the application will start tracking satellites*

After a GPS device has been connected once the CI-110/120 software will attempt re-connect this GPS device every time the application starts.

Entering your calibration data

NOTE: IF YOUR CI-110 WAS BUNDLED WITH A HANDHELD OR LAPTOP COMPUTER THIS STEP CAN BE IGNORED SINCE CALIBRATION VALUES ARE ENTERED AT THE FACTORY.

1. Click the **Advanced Settings** button.
2. Click the PAR Sensors **Calibrate** button.
3. Enter the PAR and Sunflecks Span and Zero values from the **Product Test Check Sheet** in the back of this manual.
4. Click the **Done** button.

Recording your first measurement

5. Attach the CI-110/120 hardware via USB to the computer.
*The **Start**, **Measure** and **Save** buttons will be enabled once the device is detected.*
6. Click the **Start** button.
This will cause the round image area on the right to be updated with a live video stream from the CI-110/120 device.

7. Place the CI-110 under the canopy area to measure. Be sure the camera is facing north for accurate readings (as indicated by the compass needle which turns green when aiming north).
8. Click the **Pause** button to preview your measurement. Adjust the Brightness, Contrast & Gamma, etc. as needed to increase the contrast between sky and foliage.
9. Click **Data** and **Edit** to view your measurement details and make changes.
10. Click the **Save** button. *The application will save your measurement. To review your measurement click on the Review tab. After saving the app will automatically go back into live video mode.*

Application Functionality

Below are summaries of each application tab and their purpose. The sections that follow detail application functionality are user interaction.

Measurement

This tab is used to record measurements and view their details. The data on this screen is stored with each measurement record, along with settings and other information (see *Application Output*).

Browse Records

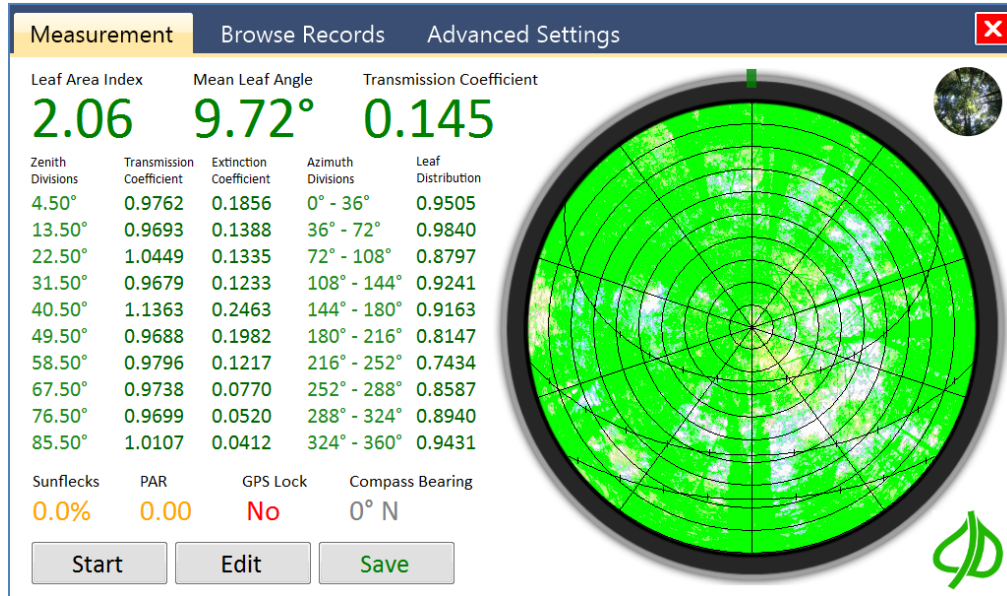
This tab is used to search, export, delete, edit and review saved records.

Advanced Settings

This tab is used to configure the app and calibrate the device.

Measurement Tab

This tab is used to record measurements and view their details. The data on this screen is stored with each measurement record, along with settings and other information (see *Application Output*).



Start/Pause button

Clicking the Start button enables a live video feed from the CI-110 device or displays a dialog to select an image file (when the CI-110/120 is not physically attached). Clicking the Pause button stops the video feed and changes the button text back to Preview.

Data/Edit button

Clicking the Data button measures the current image and displays statistics. Clicking the Edit button displays the options to manipulate the measurement image.

Save button

Saves the current image and measurements. The folder and format used to store measurements can be configured in the Advanced Settings tab. Review the *Application Output* section of this document for details on the data saved.

Original / Measured Image Toggle button

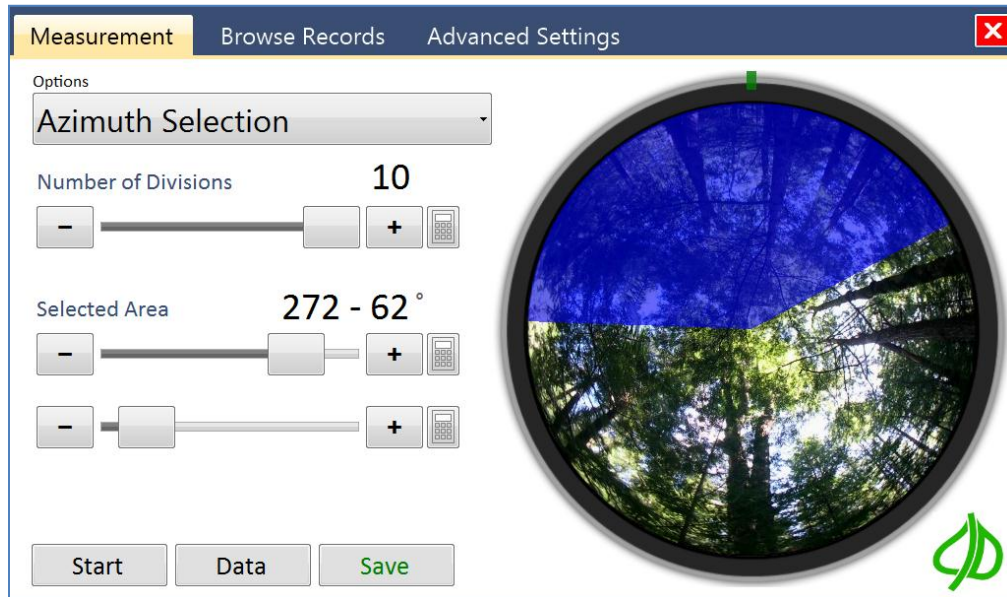
In the upper right corner of the screen is a tiny preview of the measured image or original camera image. Clicking on this small circle toggles the image displayed between these two.

GPS Lock

This indicates if there is a GPS satellite lock on your current position. Records saved without a GPS Lock may store the wrong GPS location, or no GPS location. The text will toggle from a red "No" to green "Yes" when a GPS lock has been acquired.

Azimuth Selection

This screen allows users to control how the measurement is separated in azimuth divisions, and select the area to be measured.



Number of Azimuth Divisions

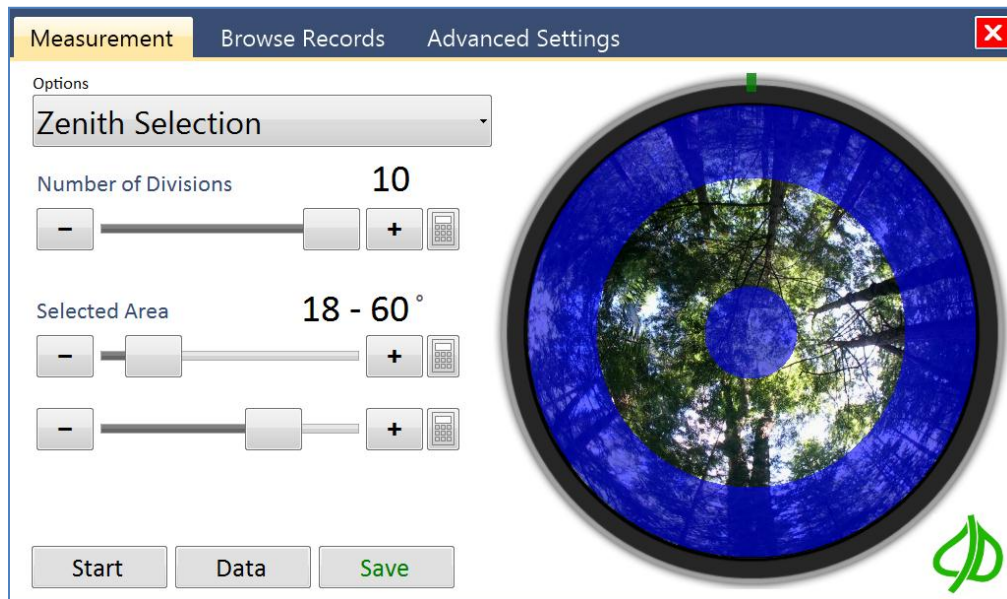
This field indicates how measurement data will be divided. Measurements can automatically be split into up to 10 azimuth divisions.

Selected Area

These fields indicate which part of the camera image should be measured. The area masked in blue or black will be excluded. In addition to using the slider controls users can select using their finger by sliding a finger clockwise over the area to exclude, or counter clockwise over the area to exclude.

Zenith Tab

This screen allows users to control how the measurement is separated in zenith divisions, and select the area to be measured.



Number of Zenith Divisions

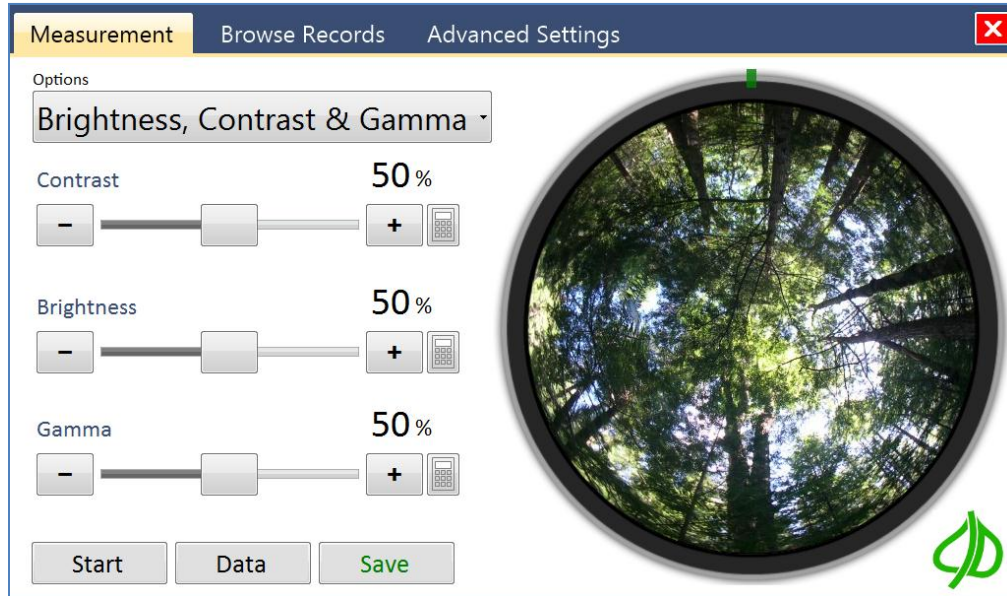
This field indicates how measurement data will be divided. Measurements can automatically be split into up to 10 zenith divisions.

Selected Area

These fields indicate which part of the camera image should be measured. The area masked in blue or black will be excluded. In addition to using the slider controls users can select using their finger by sliding a finger clockwise over the area to exclude, or counter clockwise over the area to exclude.

Brightness, Contrast & Gamma

This feature is used to optimize the image for accurate processing. These settings can be manipulated at any time. For example, measurements can be recorded outside then later optimized inside where it's easier to see the computer's display.



Contrast

Controls the ratio between brighter and darker pixels in the measurement image.

Brightness

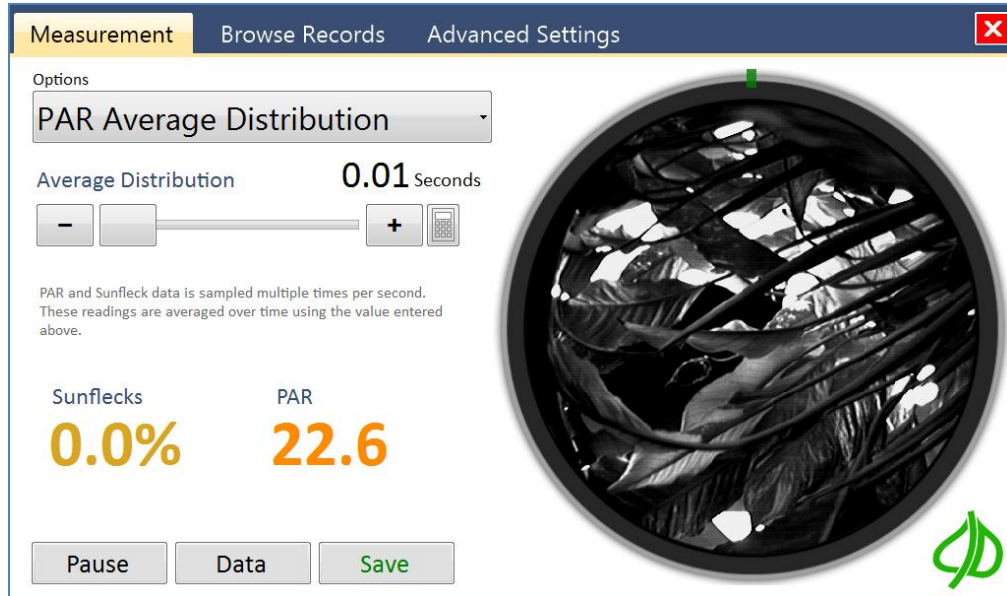
Controls the luminance of the measurement image.

Gamma

Controls the gamma correction of the measurement image.

PAR Average Distribution

This feature is used to change the way PAR data is recorded. PAR data is averaged across the amount of time selected in this screen. This can be useful to capture an average reading from an entire area vs. a single reading value from a specific location.



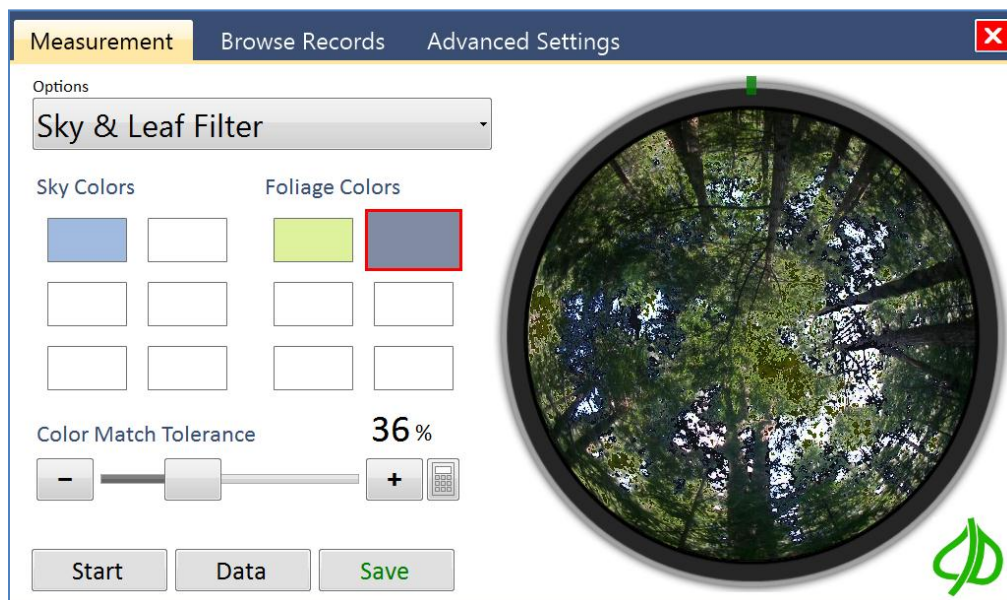
Average Distribution

Adjust this to control the amount of time PAR data is averaged over.

Sky & Leaf Filter

This feature allows users darken specific colors (foliage area) and lighten others (sky area).

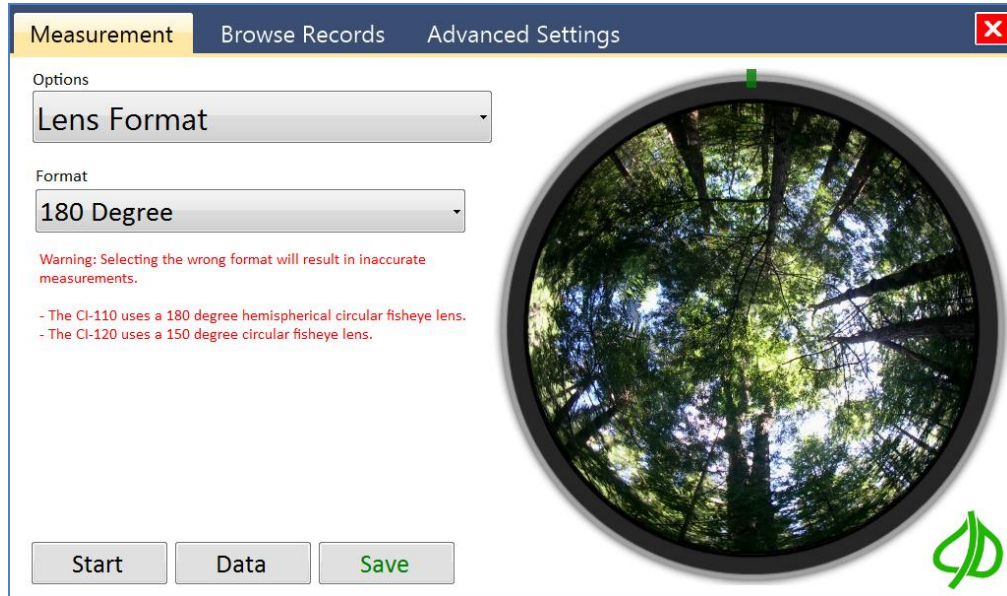
In the example below foliage colors that should be green are blurred by the sky with a blue hue. After applying the Sky & Leaf Filter the image on the right shows those areas are darkened so they will be counted as foliage instead of sky...



To use this filter click on a color square, click on the color in the image to work with and then select the "Color Match Tolerance". Increase this tolerance to include pixels with colors similar to the selected color.

Lens Format

This feature allows users to toggle between using a 180 degree hemispherical lens and a 150 degree lens. The CI-110 is delivered with a 180-degree lens, the CI-120 is delivered with a 150-degree lens.

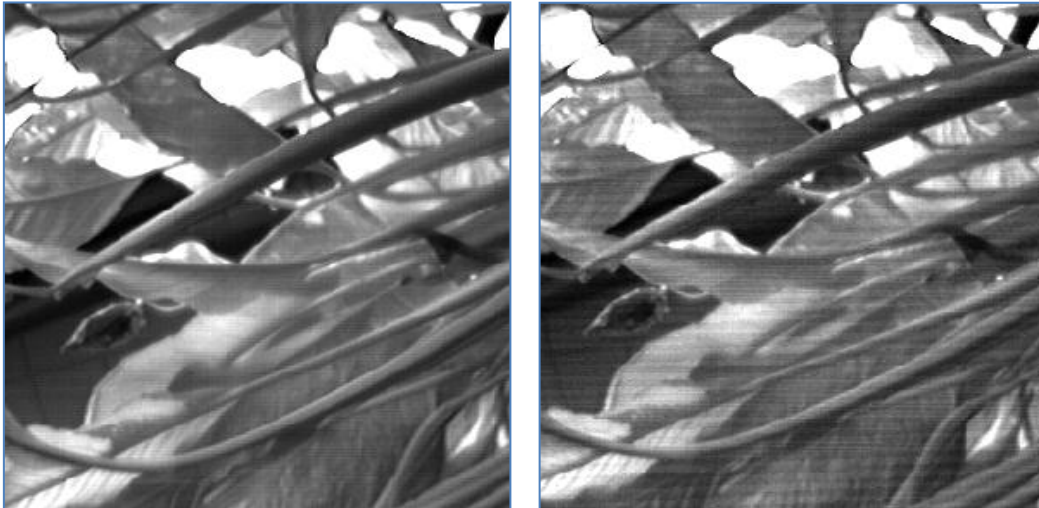


Lens Format

This should be 180-degrees for the CI-110 and 150-degrees for the CI-120 (unless a lens modification has been made).

Image Stacking (HDR)

Stacking photographs reduces scan-lines while increasing resolution and dynamic range. This is accomplished by overlaying multiple images (or frames) which causes static contents (such as the plant) increase in detail while dynamic content (such as scan-lines) become less pronounced. Illustrated below in these two images, Image Stacking was applied to the image on the left)...



Note: This feature is currently only available for the analog CI-110.

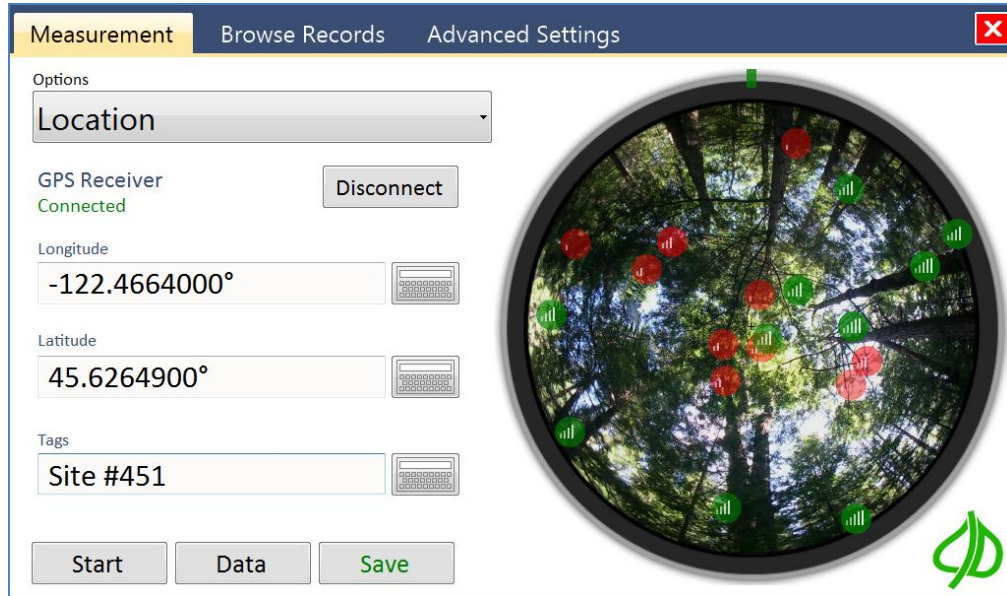


Stack Size

This controls the number of images or frames the camera uses to build the measurement image. Large stack sizes can exhaust PC memory, USB bandwidth and CPU.

Location

This tab is used to specify the location of the CI-110/120 device. Users can choose to enter Longitude and Latitude manually, use a GPS device or enter a text based tag to identify different locations.



Connect/Disconnect button

This button connects or disconnects a GPS device to the CI-110/120 application. When pressed to connect the application will search your system for a GPS device. If found the round image area on the right will be updated with the last camera image and an overlay of the GPS satellites above.

Longitude and Latitude

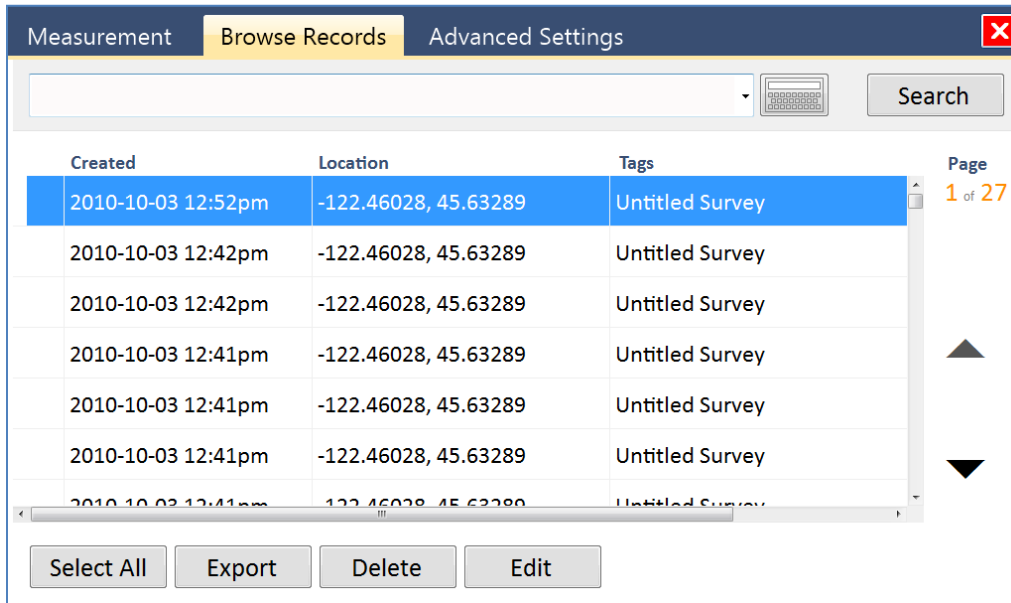
These values can be changed by clicking the keyboard icon or typing within the field.

Tags

This field can be used to store text that identifies a specific location, project or other details. For example, "Project #57, Flag #101" might denote the project and measurement plot location. This is especially useful where GPS is not usable, or if the host computer does not have a GPS device.

Browse Records

This tab is used to browse through measurement records. Clicking a specific record will cause the application to load that record.



Search Keywords

This textbox can be used to filter results in the Review tab. Type a value then click the Search button to only show records with that value. Click the Reset button to clear this value.

In the example above "Project #57" was typed, which is why only records with those keywords appear. In this hypothetical scenario GPS positioning was unavailable, flag numbers denote measurement plots.

Previous and Next buttons

Only 5 records are displayed on the screen at one time. These buttons move forward and backward through the complete set of records.

Export button

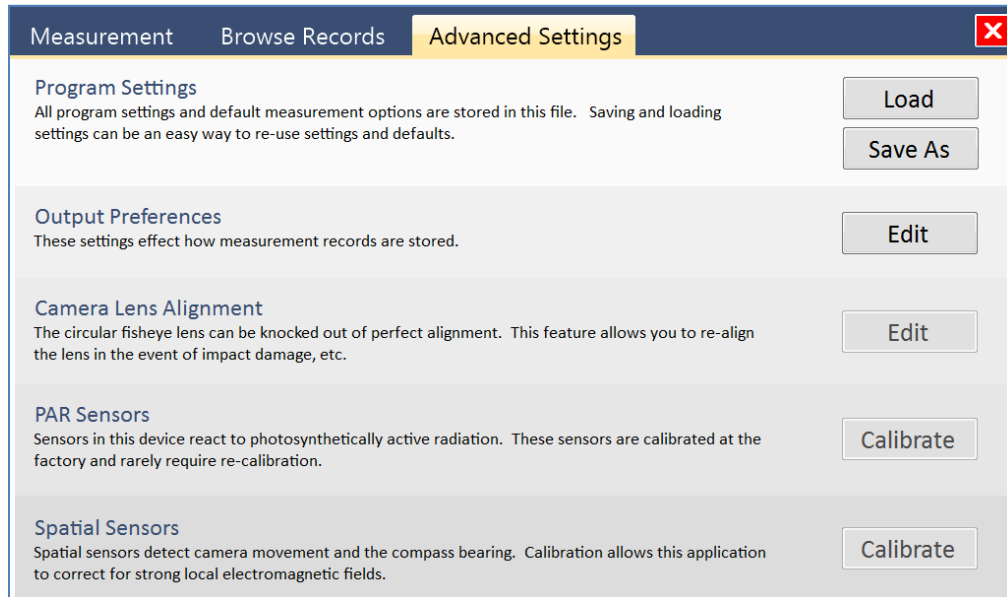
This button creates a KML (Keyhole Markup Language) file using the selected measurement records (indicated by green checkmarks).

Delete button

This button deletes the selected measurement records (indicated by green checkmarks). Records deleted here are moved to the Windows Recycle Bin. They can be undeleted from the Recycle Bin just like other files in Windows as needed.

Advanced Tab

This tab is used to control features in the software that are not typically changed between measurements.



Output Preferences

This tab is used to control features in the software that are not typically changed between measurements.

Measurement Browse Records **Advanced Settings**

Output Folder
This is the folder new records will be saved to when the Save button is pressed on the measurement tab.

C:\Users\CI110User\Pictures\CI-110 Browse

Output Filename Prefix
The text below will be used as a prefix for new records. For example, if "Untitled" is entered below files with names like, "Untitled_1009202119200.png" will be created.

Untitled Browse

Image Format & Size
Images will be saved in the size & format selected below.

BMP 2048x1536

Cancel Done

Settings File

The **Settings File** textbox contains the path to the application's settings file. Use the **Load** button to import settings, click the **Save** button to record settings in the settings file.

Note: Settings are also saved automatically when the application is closed.

Output Folder

The **Output Folder** textbox contains the path to store measurement records (see *Application Output*). Use the **Open** button to explore the folder and view files. Use the **Browse** button to change the output folder by browsing to your selection.

Output Filename Prefix

The **Output Filename Prefix** contains the prefix to use for new measurement records. For example, a prefix of "CI-110 Demo Survey_" would cause all new measurements to be saved as files with that prefix. This can be used to keep project data organized within the application and elsewhere.

Output Image Format

The **Output Image Format** selection specifies the image format to use for each "raw" and "measured" image (see *Application Output*).

Application Output

By default CI-110/120 images and data will be stored under the Windows user's Pictures folder in a subfolder called CI-110. Each measurement is saved in four separate files...

1) *The "raw" image file.*

This file contains the raw camera image. The format of this file is controlled by the "Output Image Format" option under the **Advanced** tab.

2) *The "measured" image file.*

This file contains the image after being measured. The format of this file is controlled by the "Output Image Format" option under the **Advanced** tab.

3) *The settings file.*

This file contains the settings at the time of measurement including...

- *Azimuth Selection information*
- *Zenith Selection information*
- *Image Threshold*
- *Viewable Range*
- *Sunflecks and PAR calibration data*

4) *The data file.*

This file contains measurement data including...

- *Timestamp*
- *Sunflecks*
- *PAR*
- *Leaf Area Index*
- *Mean Leaf Angle*
- *Transmission coefficient for diffuse penetration*
- *Zenith Divisions, Transmission coefficient, Extinction coefficient*
- *Azimuth Divisions, Leaf Distribution*
- *Longitude and Latitude*
- *GPS Quality, Number of Satellites, GPS Lock indicator*

Tips

This section of the document outlines tips for various use cases.

Canopy Gaps

The CI-110/120 employs the gap-fraction computation method and assumes random leaf distribution. A non-uniformly distributed canopy with gaps will cause over-estimations of the solar beam transmission and under-estimations of LAI.

In circumstances that do not satisfy the assumption use the Zenith and Azimuth selections to exclude large canopy gaps, and make multiple measurements then average your results. The number of measurements needed for averaging depends on the canopy structure and its distribution.

Canopy Size

Observe the canopy size. If the plot is too small, the fish-eye lens' field-of-view will extend beyond the edge of the foliage being measured, and LAI will be underestimated. The reverse is true when measurements are taken in a plot surrounded by a denser canopy.

The suggested minimum plot radius from the fish-eye lens is approximately 3 times the plot height. The exception to the suggested minimum plot radius is in dense plant canopies, less distance may be required because the fish-eye may not be able to see to the edge of the canopies.

If you must measure a small plot adjust the Zenith and Azimuth selections to exclude everything beyond your plot.

Distance from Canopy

The distance from the CI-110/120 lens to the leaf at an angle of 30° from zenith should be at least four times the leaf width.

Sky Conditions

The optimal sky conditions for measurements are under even cloud coverage during early morning or late afternoon (when the amount of scattered radiation is low). Under sunny sky conditions the lens should be shaded to minimize to prevent underestimation of LAI and overestimation of solar beam radiation and diffuse radiation.

Row Crops

One measurement technique is to take four evenly spaced readings along a diagonal transect that runs between two rows, and to do several transects to prevent the same few plants from dominating the entire set of readings. It is best not to excessively weigh the "in row" or "between row" situations.

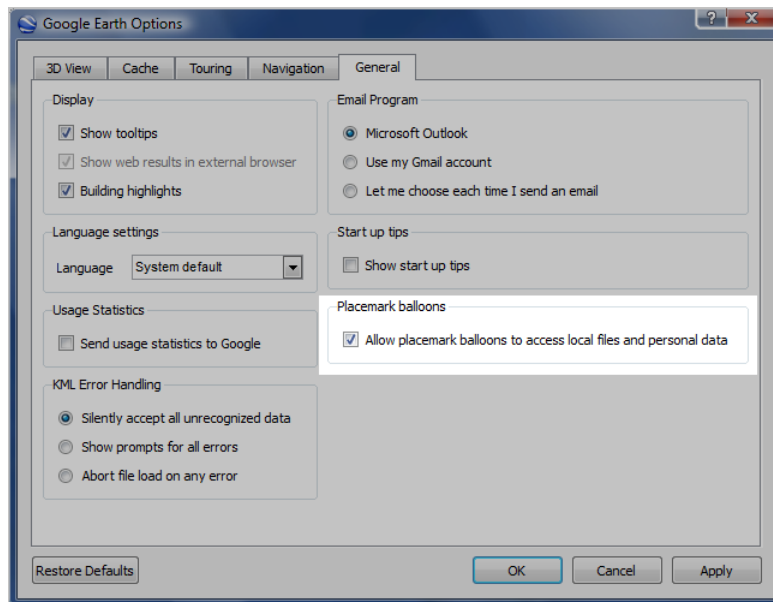
Troubleshooting

This section of the document outlines suggestions to resolve issues using the CI-110/120 software.

Google Earth displays icons instead of CI-110 images.

Google Earth is commonly used to read the KML files exported from the CI-110/120 application's Review tab. By default Google Earth does not allow you to load KML files from your local drives. To resolve this issue follow the instructions below...

1. Start **Google Earth**
2. Click the **Tools** menu at the top of the screen.
3. Click **Options**.
4. Click the **General** tab.
5. Check ***“Allow placemark balloons to access local files and personal data”***.



6. Click **OK**.
7. Reload your KML file, or exit Google Earth and restart it from the CI-110/120 application.

Frequently Asked Questions

Below are some frequently asked questions about the CI-110/120 software and hardware...

How can I load existing images on my computer?

Browse to the image you want to use, then drag-and-drop your image on the Measurement screen.

Why is the image so dark?

The CI-110 camera was modified to use a blue lens, the contrast and other parameters have been adjusted for optimum accuracy. Indoor lights aren't usually strong enough to show anything other than a dark or black image.

Where are the PAR sensors located?

The PAR sensors are located in the stick the camera connects to.

Which side is up on the stick and camera?

The bottom of the camera mount has a cable attached to it and the stick has opaque white plastic on the top.

The handle on the stick get warm, is this normal?

Yes, this is normal. The power to run the PAR sensors and camera run through the handle of the stick. This generates the heat in the handle.

Theory

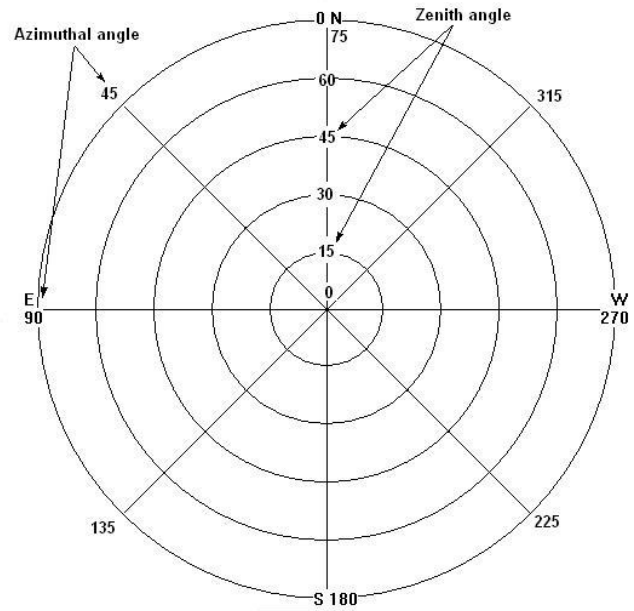
The CI-110 software calculates the solar beam transmission coefficients, or the fraction of the sky visible from beneath the plant canopy using the *Gap-Fraction Inversion Procedure* (Norman and Campbell, 1989).

Images of plant canopy are broken down into zenith and azimuth divisions. The fraction of sky (solar beam transmission coefficient) visible in each division is analyzed by tallying the sky portion of the image pixels.

A value between 0 and 1 is assigned; with 0 meaning no sky is visible below the plant canopy, and 1 meaning that the entire area is sky or no foliage coverage. A fraction number indicates partial foliage cover.

When the divisions have been analyzed, the average solar beam transmission coefficients, hemispherical diffuse radiation transmission coefficient (the sky view factor), mean foliage inclination angles, and plant canopy extinction coefficients are computed.

The key equations involved in this process are as follows...



1 τ_d : The transmission coefficient for the diffuse radiation penetration

$$\tau_d = 2\Delta\varphi \sum_{\varphi_i=\varphi_1}^{\varphi=n} \tau_{\varphi_i} \sin\varphi_i \cos\varphi_i$$

where i : the i th zenith angle division (n is the number of divisions selected by you)

$\Delta\varphi$: the zenith angle increment in radians

τ_{φ} : the transmission coefficient for the ray penetration (or the fraction of the sky visible) in each zenith angle area. 0 means that no sky is visible and 1 means that entire area is sky.

2 L: Leaf area index

$$\tau_{\phi_i} = e^{-k_i L}$$

$$K\phi_i = \frac{\sqrt{x^2 + \tan^2 \phi_i}}{A}$$

$$K\phi_i = 1 \quad \text{for horizontal leaves } x \rightarrow \infty$$

$$K\phi_i = \frac{2 \tan \phi_i}{\pi} \quad \text{for vertical leaves } x \rightarrow 0$$

$$K\phi_i = \frac{1}{2 \cos \phi_i} \quad \text{for spherical leaves } x \rightarrow 1$$

where K : the extinction coefficient of the canopy

A : a polynomial function:

$$A = x + 1.774 (x + 1.182)^{-0.733}$$

where x represents leaf angle distribution (Norman and Campbell, 1989).

3 α : The mean foliage inclination angle of the canopy

$$\alpha = \tan^{-1} x \quad (0^\circ \leq \alpha \leq 90^\circ)$$

$$x = \frac{b}{a}$$

where b : the horizontal projection of the foliage

Support

CID Bio-Science, Inc. is committed to providing customers with high quality timely technical support.

Questions and issues not addressed by this document should be directed to a Technical Support representative in your own country, or CID Bio-Science, Inc. directly.

PLEASE REFER TO THE DETAILS IN THIS DOCUMENT BEFORE CONTACTING CID TECHNICAL SUPPORT.

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360-833-1914

<http://www.cid-inc.com>

support@cid-inc.com

sales@cid-inc.com

Warranty

Seller's Warranty and Liability: Seller warrants new equipment of its own manufacturing against defective workmanship and materials for a period of one year, of a single shift operation, from date of receipt of equipment - ***the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause is not to be considered a defect.*** Any defect must be called to the attention of CID, Inc., Camas, Washington, USA, in writing, within 90 days after receipt of the unit.

Seller's liability for defective parts is limited to the repair or replacement of any part of the instrument without charge, if CID, Inc.'s examination discloses that part to have been defective in material or workmanship, and in no event shall exceed the furnishing of replacement parts F.O.B. the factory where originally manufactured. No equipment may be repaired or altered by anyone not authorized by CID, Inc.

Material and equipment covered hereby, which is not manufactured by Seller, is to be covered only by the warranty of its manufacturer. Seller shall not be liable to the Buyer for loss, damage, or injury to persons (including death), or to property or things, whatsoever, including, but without limitation, products processed by the use of the equipment; or for damages of any kind or nature (including, but without limitation, loss of anticipated profits), occasioned by or arising out of installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The purchaser is to pack, ship, or deliver the instrument to CID, Inc., in Camas, Washington, USA, within 30 days after CID, Inc. has received written notice of the defect at the customer's expense. No other arrangements may be made unless otherwise approved in writing by CID, Inc.

The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory, or otherwise (***including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose***), not expressly set forth herein.

CI-110/120 Product Test Check Sheet

Sensor Head Handle Serial Number:		
CI-110 DLP Sensor Head Serial Number:		
CI-120 Sensor Head Serial Number:		
CI-110/120 Software Version:		
Computer Model / Serial Number:		
Windows Version:		
Testing Function	Final	
CI-110/120 Software <small>(with computer)</small>	Installed:	
	Verified:	
CI-110/120 Software <small>(without computer)</small>	Verified:	
PAR Calibration	PAR Zero Calibration:	
	PAR Span Calibration:	
	Sunflecks Zero Calibration:	
	Sunflecks Span Calibration:	
Environmental Tested		
Image Capture and Adjustment Functions	Focused Image:	
	Centered Image:	
CI-110 Plant Canopy Image Test Date:		
Comments		