Halio Automation

HALIO®

Smart-Tinting Glass

The Halio Advantage

Halio smart-tinting glass is the world's most advanced natural light management system. The result of a decade-long development by Kinestral Technologies, Inc., Halio is the culmination of the fundamental re-engineering of electrochromic glass technology, providing unparalleled tinting speed, uniformity, and responsiveness to ever-changing environmental factors and individual occupant preferences.

Highlighting Halio's next-generation capabilities is its automation system, a sophisticated combination of secure APIs, sensors, controls, and learning algorithms that integrate easily with any network.

To see how this innovative architecture provides a world-class user experience while continually optimizing for peak performance, let's explore the Halio Automation System in greater detail.

Core Capabilities

Every automation environment is unique, with its own specific daylight conditions to consider. The Halio Automation System is designed and configured to respond in real-time to these conditions without the need for occupant intervention.

To do this, the automation system leverages three core capabilities:

Direct Sun Control	Accounts for the time of day, day of the year, neighboring buildings and other possible obstructions, and how far the sun shines into a building. It also manages solar heat gain and glare to provide thermal and visual comfort as well as energy savings.
Daylight Maximization	Ensures that the window tint is as clear as possible when direct sun is not an issue.
Obstruction Mapping	Allows automation to account for shadowing from external objects such as neighboring buildings or window overhangs.

The Halio Site Audit: Customizing Automation for Each Smart Window

Prior to installation, Halio technicians conduct a project audit to establish configuration settings for each Halio window, using information from the drawings and specifications. Each smart-tinting window is individually configured for each location.

After installation, a Halio technician visits the building to conduct a site audit. At this time, the Halio technician confirms that the window configuration settings match the customer's intentions and are accurate for the building, including:

- Latitude and longitude of the building
- Orientation and tilt angles of each window
- Identify exterior objects that can cast a shadow into the window, as well as generate maps of potentially obstructing objects

How Halio Automation Works

Halio evaluates sky conditions every 30 seconds. When conditions change, Halio will adjust window tint levels accordingly. During the 30 second update Halio performs the following action for every window.

- Check the position of the sun relative to the window
- Check the obstruction map to see if sunlight reaches the window or is blocked by an obstruction
- Check the allowable sun map to see if the sunlight shines too far into the building
- Set the tint level for the window based on brightness, sun position, and sunlight propagation

The Position of the Sun Relative to the Window

The position of the sun relative to the window at any given time during the year can then be calculated. See Figure 1 for a comparison of how this differs between summer and winter.

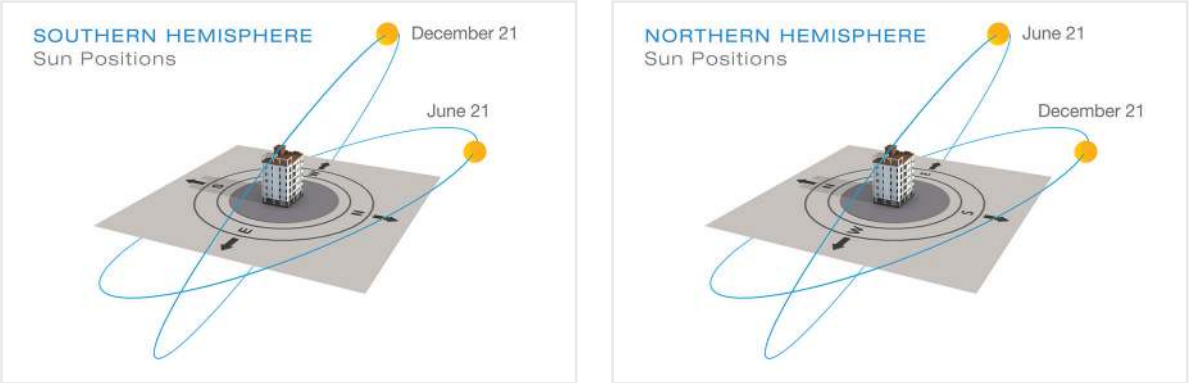

Figure 1: Sun position in the sky for the northern and southern hemispheres on June 21 and December 21

Does Sunlight Reach the Window?

Halio uses obstruction maps to determine if permanent objects have potential sunlight exposure. We use three methods to create obstruction maps: geometric, ray tracing, and photographic. Let's take a closer look at the photographic method.

First, a photograph is taken looking out the window using a calibrated fisheye camera to capture the exterior context (Figure 2).

Figure 2: Photograph of objects outside window

Visible regions of the sky are identified in the image (Figure 3). When the sun is in the region of the sky visible from the window, then the window will receive sunlight. When the sun is in a region of the sky that is not visible (i.e., obstructed by buildings or overhang), the window will be in shadow.

Figure 3: Area where sun may directly shine on window

Note: By default, obstruction mapping does not account for impermanent features like trees. However, the Halio Audit Team can include such features in their calculations if needed.

The camera is calibrated so that the horizontal azimuth and vertical profile angles to each pixel are known (Figure 4). This data, combined with the previously calculated sun path data, allows Halio Automation to determine when and if the window will get direct sun for any given day of the year.

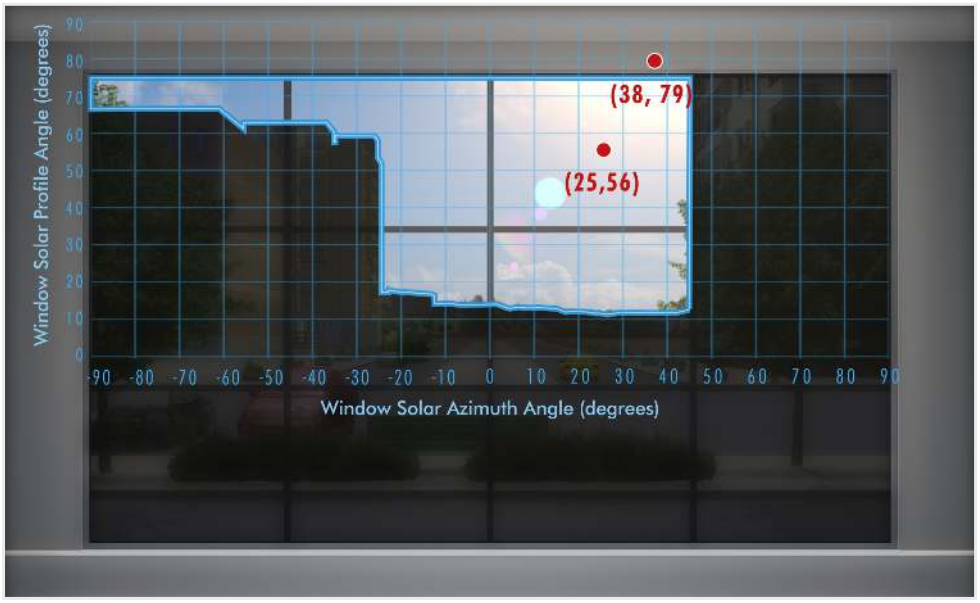

Figure 4: Angular obstruction map

The Distance the Sun Shines into the Building

Halio Automation utilizes an allowable sun map to designate where sunlight is problematic and where sunlight is allowable or even desirable for each room in a building. They are used to account for room-to-room preferences like workstation positioning.

Allowable sun maps are angular maps (in window coordinate space) and are created using geometric dimensions, ray tracing in a 3D CAD model, or with photographs. Let's take a closer look at the photographic method. First, an orthophoto is taken of the room from the window (Figure 5).

Figure 5: An orthophoto is taken to determine areas of a room where sunlight is not desired

Within the photo, undesirable areas for sunlight are identified. An allowable sun map is then generated (Figure 6).

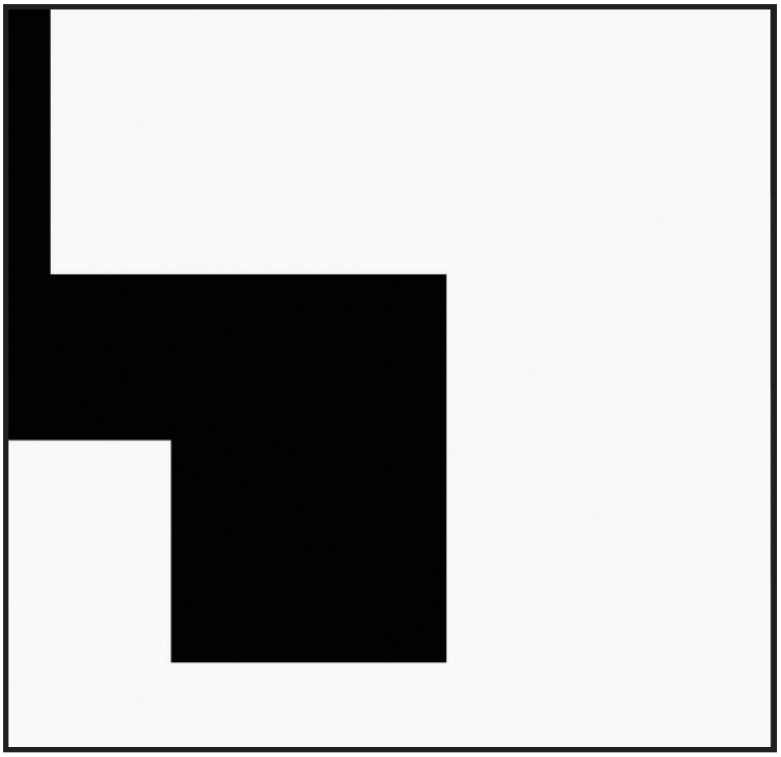

Figure 6: Allowable sun map created from orthophoto

While the photographic allowable sun maps are visually the easiest to understand, Halio most commonly uses geometrically generated allowable sun maps. Geometrically generated maps are created using the following geometric parameters (Figure 7):

- **Allowable propagation distance** is determined at a defined height above the floor, usually determined by the work surfaces in the room (Figure 7).
- **Allowable propagation height** is the height above the floor at which propagation distance is measured.
- **Window head height** is the top of the window measured from the floor.

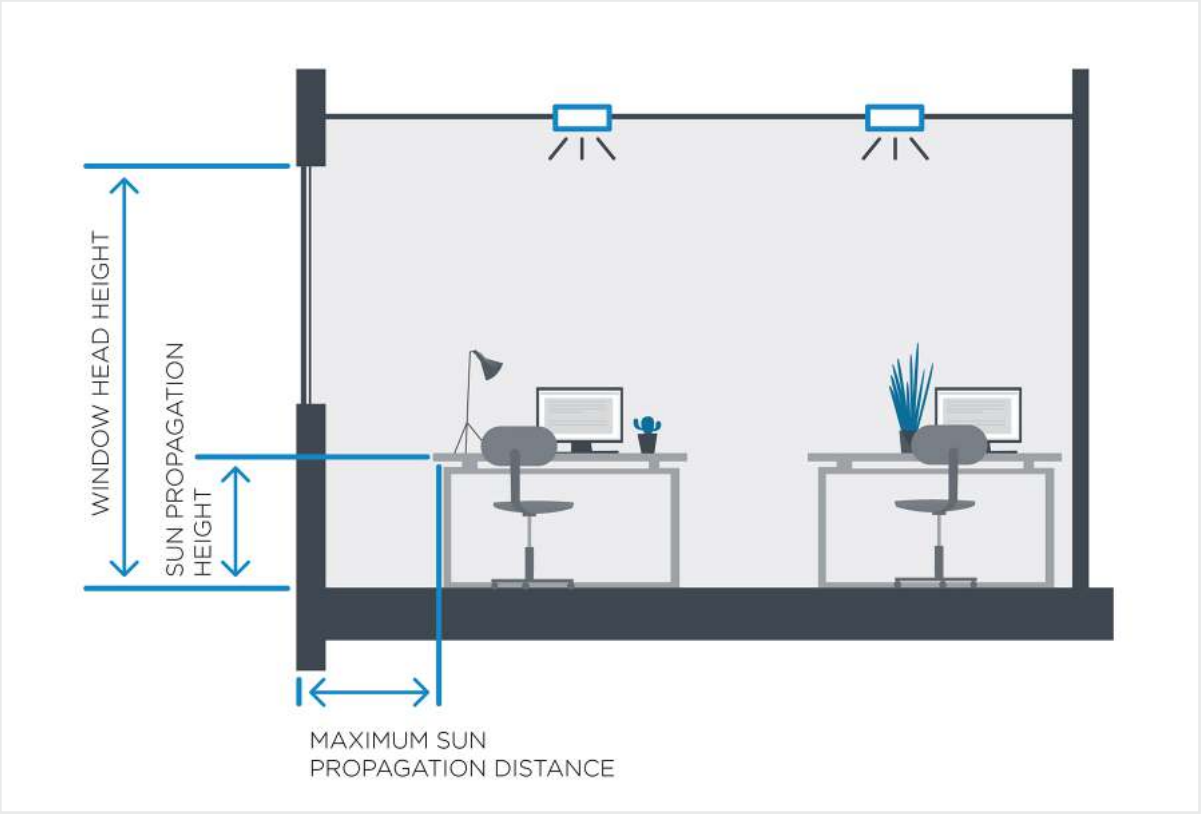

Figure 7: Determining maximum sun propagation distance

Measuring Brightness to Determine Window Tint

Halio Automation considers two attributes when determining how much a window needs to be tinted:

- The brightness of the sun
- The position of the sun in the field of view

Halio Automation uses a sophisticated roof sensor that independently measures the brightness of the sun and sky. The measured brightness of the sun includes atmospheric effects such as humidity and clouds, which attenuate the sun. This measured sun brightness is then compared to the low and high glare thresholds configured for a given room before Halio automatically adjusts the window tint to ensure that glare is maintained within the acceptable threshold for the room occupants. The low and high glare thresholds can be adjusted at any time to suit occupant needs and preferences.

Changing Weather Conditions: Managing Rapid Tint Cycling

Halio's industry-leading tint speed makes it the most responsive electrochromic glass product on the market today. Too much responsiveness, however, can lead to rapid tint cycling, an undesirable effect on partly cloudy days when sunshine changes frequently throughout the day.

To manage these scenarios, Halio Automation continues to tint quickly in direct sunlight but waits several minutes during brief periods of cloud cover before reducing the level of tint. This prevents rapid cycling while maintaining optimum daylight conditions. Should the cloud cover persist, Halio will gradually clear the window to allow for more light.

The Halio Cloud System

The Halio Cloud System is the key component in automating Halio smart glass. Using best-in-class third-party modules and a secure API, Halio Cloud offers robust options for extending capabilities and integrating with other building automation systems.

This modular approach ensures that as cloud technologies advance, the Halio Natural Light Management System continues to provide full functionality. See Figure 8 below for an example of a Halio network diagram.

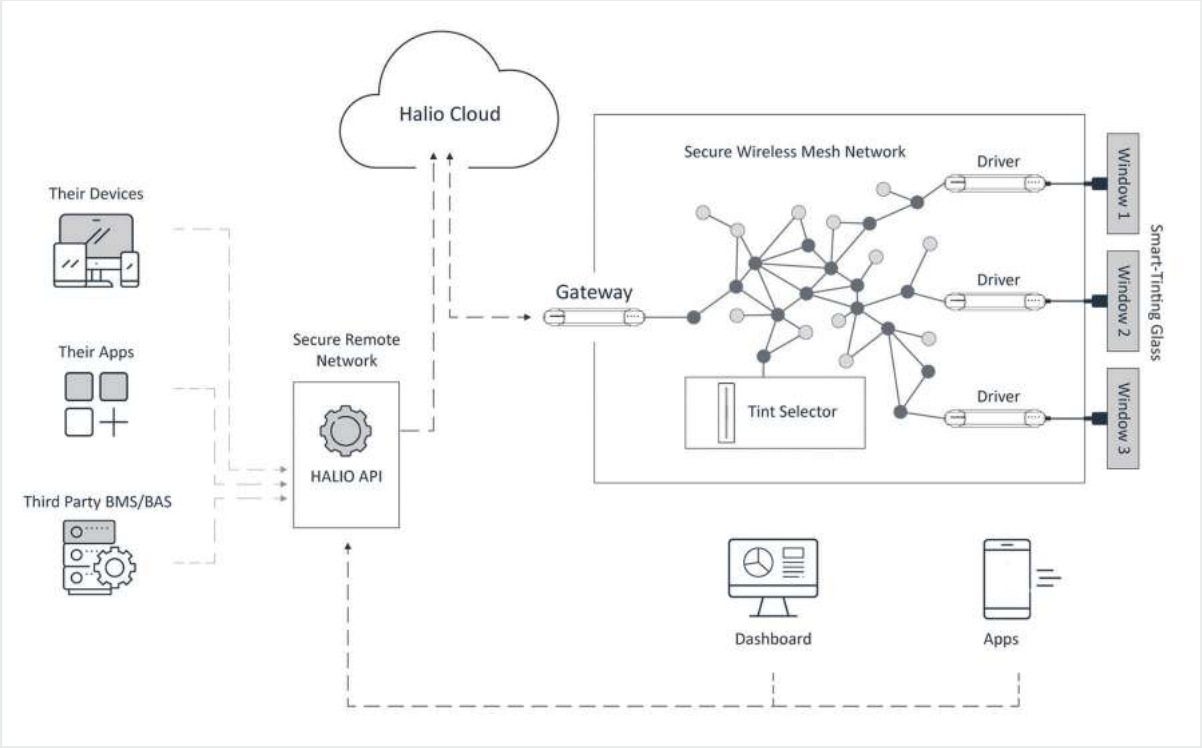

Figure 8: Example of a Halio network, including Halio Cloud, Halio Gateway, and the API

24/7 Monitoring Provides Instant Window Status Updates

The responsiveness of Halio smart-tinting glass would not be possible without constantly monitoring the status of each window in the network. This provides powerful performance data that can be used by the system itself or by facility management personnel:

- **Window Health.** Window performance can be monitored in real-time. In the case of breakage, an emergency situation, or another incidental occurrence that requires attention, the Halio system will send an alert.
- **Tint Speed Matching.** No matter the assortment of window sizes or configurations, the Halio system can monitor and match tint speeds to ensure uniform aesthetic appearances and predictable facade or interior partition behavior.
- **Unlimited Tint Levels.** By knowing the exact state of each window, the Halio system can precisely select any tint level within the tint range to suit your needs.

Summary

The Halio Automation System is leading the smart glass revolution as the most advanced and innovative cloud management architecture in the industry. Halio engineers are continually developing and implementing solutions to challenging automation hurdles like reflected glare, energy minimization, and learning algorithms in order to meet increasingly more demanding building and occupant needs for automatic natural light management.

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