Look.

Turn Magic Leap into a scientific tool. Ask quantitative, spatial questions in realtime – receive data/plots in HUD.

Problem In field science (the study of our natural surroundings) measurement and analysis constitute a major bottleneck. Out in the field, time is spent making repetitive, spatial measurements (position, distance, size, count, etc.) with specialized tools. After returning to lab, these measurements are analyzed with computer software, ultimately providing a quantitative answer to the scientist's question. The questions are exciting, but the manual measurement and delayed analysis turn-around are often tedious and even prohibitive.

Solution Magic Leap's augmented reality headset is uniquely suited to improve field science methods. In a single, portable package that feels like a natural extension of the user's eyesight, Magic Leap is able to (1) quantify the spatial and color components of a user's vision and (2) analyze and present that data in real-time. With *Look*, the augmented scientist can hone this tool to their specific needs, choosing exactly which data to collect as well as how to analyze and present it. Devices of this type will replace specialized measurement tools in field science and enable a more organic scientific process, less disjointed by the discrete steps of measure->record->analyze.

Implementation *Look* turns Magic Leap into a spatial measurement tool for scientists. The application consists of three primary components: data selection/analysis modules (*see below*), a GUI for creating tools from those modules, and a heads-up user display (HUD) which encompasses the user's visual experience as they use their tool. *Look* will contain a downloadable set of common field tools, but because scientific questions can be very particular, it is critical that users have the ability to create their own (*see next page*). Measurement data will be storable and extractable to enable communication of results and additional analysis elsewhere.

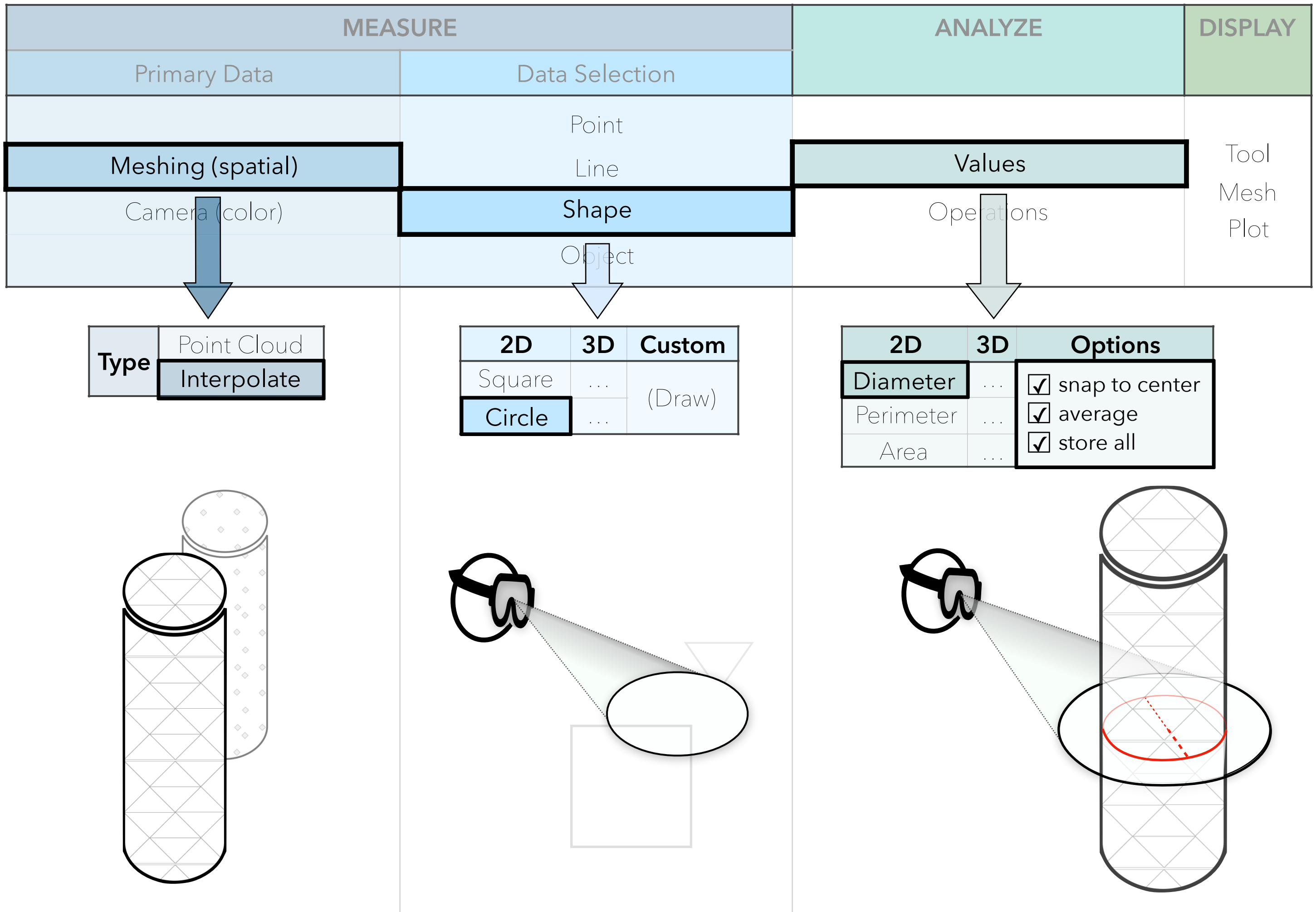
MEASURE		**ANALYZE**	**DISPLAY**
Primary Data	Data Selection		
	Point		Tool
Meshing (spatial)	Line	Values	Mesh
Camera (color)	Shape	Operations	Plot
	Object		

Modules: measurement, analysis, and display functions that can be mixed and matched to create custom tools.

Use case An ecologist would like to slow the growth of an invasive plant species to preserve the local ecosystem, but first she has to understand which environmental factors govern the plant's growth. In each 10x10m plot of land, she requires the following 3 measurements: tree trunk diameter, percent canopy cover (how much sky is visible through the canopy), and the relative positions of individual plants. Typical field methods would involve some combination of a GPS, ruler, camera, notepad, and by-eye estimates, but today she is going to use *Look* with Magic Leap.

Her *Look* app has pre-loaded tools for percent canopy cover and and relative position, but she'll have to create a new tool for tree trunk diameter. To do this she enters the tool-making GUI, combines some of its modular functions (*see next page*), tests the tool to make sure it is functioning properly, and gets to work. Rather than switch between multiple pieces of physical equipment, she is able to look, point, and click her way through the landscape. The process is less cumbersome, faster, and includes real-time feedback. As observations are stored, a quantitative picture is painted by the custom plotting function in her HUD, so instead of waiting to get back to her lab computer for answers, she gets them immediately. With time saved and an adaptive toolkit in hand, she can interpret her results, decide what observations are needed next, make or download the requisite tools, and go.

Use case (continued) *Below, the tool-making GUI is depicted in-process as the user builds a measurement tool. Each step has an associated illustration to convey its effect on the final product. At the bottom is a table which further elaborates on each module's contribution.*



<u>Tool GUI</u>: a graphical interface for combining modules to create new custom tools or edit existing ones. The example portrayed is for tree trunk diameter, but it generalizes. The tool works as follows…

Primary Data –> Meshing –> Interpolate:	Guided by the user's gaze, a <u>continuous mesh (field of spatial coordinates) will be created</u> describing the surface of the tree trunk. This mesh grows and fills in as the user views the trunk from different angles.
Data Selection –> Shape –> Circle:	A 2D circle will be projected from the user's headset. Circle size, position, and angle can be adjusted via handheld controller input. When the trigger is pressed, <u>any mesh which intersects with the circle is 'selected' for analysis</u>.
Analyze –> Values –> Diameter + Avg:	<u>At each possible angle (0-180°), a line is drawn across the center of the circle and the furthest distance between mesh-points on that line is measured</u>. The circle will automatically center itself on the trunk, ensuring an accurate measure of diameter in every direction. All values are stored, while the average is displayed in the HUD.

Notes:

- *Unlike standard methods, this tool easily accounts for the irregularities of trunk shape (most trunks aren't perfect circles).*
- *The user need not mesh the trunk from all angles to get an estimate. Only angles with mesh-points on both sides of the circle will count towards the average value, so half a trunk will do if a full scan isn't possible or time is of the essence.*
- *There is no one right answer. Another user might create the same functionality with a different combination of modules.*

Considerations *Accuracy and Environment Dependence*: Does the Magic Leap make science-grade measurements? It depends on the measurement you need and your environmental conditions. The device, like all measurement tools, has fundamental range, resolution, and accuracy limits. In addition, its ability to track the user's head angle (and therefore accurately project content) is dependent on lighting – not too bright, not too dark. Its ability to mesh a material (and therefore accurately measure) is dependent on the material's IR absorbance and reflectance.

The *Look* team recognizes that these points are a make-or-break for our users, and as such, has made them a top priority. We are quantifying performance across a broad range of natural settings and materials, the results of which will be publicly available. When possible, we will notify users of simple tricks they can use to improve their measurements (e.g. average over multiple scans of the same object) or environment range (e.g. supplement lighting conditions with shades or headlamps). Going forward, we are confident that range, resolution, accuracy and the spectrum of viable environments and materials will continue to increase. Magic Leap has an economic incentive to improve the user-experience of the device – broadly, how *real* the experience feels – which ultimately requires them to improve the device's sensing capacities.

Academic Market: Magic Leap has only just launched, so it is unlikely that *Look's* initial customers will already have a device. Therefore, in the beginning, each unit of application purchase will have to be matched by a Magic Leap purchase. We do not foresee this being a significant monetary barrier to government grant-funded scientists, especially given the value added by the device+app to their workflow. To our knowledge, there are few other augmented reality devices or applications targeting professional academics at this time, giving Magic Leap and *Look* a mutual opportunity to populate the niche.

Vision Empowered by Magic Leap, *Look* will be a major improvement to current field methods in terms of time, labor, and expense, but perhaps most interesting is how it affects the user's psychology. Never before has this amount of quantitative data about a human's visual field been available to them in real-time, in their visual field. *It is akin to a quantitative sixth sense*. The experience evokes new ideas – new questions about the world. Augmented reality will be a rich addition to science technology, and *Look* intends to lead in its introduction to the community.

Roadmap: immediate next steps

Measurement	Selection	Analysis	UI + User Testing
• User-directed meshing protocols • Map 2D RGB camera values to 3D mesh • Quantify range, resolution, and accuracy limits • Quantify environment and material limits	• 1, 2, and 3D shape-mesh intersect selection • 'Lasso' selection (custom shape) • 'Object' selection: point at real-world object – select only the mesh/color data describing it	• Shape-dependent values (e.g. 'diameter') • Smoothing and thresholding • Custom equation builder	• HUD and Tool-GUI • Iteratively test and revise in field conditions with clients

At first, we will focus on augmenting field science methods. Once the Magic Leap's current measurement limits are reached and clear demand is present, we will supplement with data from other sensing devices. Immediately obvious examples of this are 3D microscopy and landscape scans. Because of their relative scales, these structures cannot be directly observed by human vision, so the Magic Leap's physical scanners are not of use. However, once (or while) the data is taken, it can be expanded or shrunk to human size and projected into the user's visual field. [*Imagine a giant neuron floating on your desktop or a miniature Mt. Fiji coming out of the floor.*] Once projected, the same measurement tools we use on physical materials can be used on these digital materials.

For human-scale observations, remote sensing supplements include cameras, microphones, IR depth sensors, sonar, radar, and LiDAR among others. Each may be stationary, hand-held, or mobilized on drones. Combined with Magic Leap, all can increase the amount of data we see in the world around us. Not only can they quantify what we see, they can see places we can't. In the long run, we intend to offer scientists quantitative sensory access to all 3 mediums of life: air, soil, and water. [*Branches above you, roots below you, a flock of birds, a school of fish… all you have to do is Look.*]

Finally, if Magic Leap – a consumer electronic – becomes a trusted asset of scientists, then suddenly the general public will have in their possession a powerful observational tool that takes standardized measurements. This empowers non-professionals to make contributions that professionals trust. We imagine this as a bridge between scientists and the general public where people can not only learn by doing, but *learn by helping*. Indeed, in some cases scientists may need help. Ecological and climate crises are an immediate and growing concern. These are global scale phenomena that require global scale observations to fully understand and address. Scientists are hard at work, but with the right tool, anyone can help.