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Leaf++: Augmented Reality and the Third Landscape

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ABSTRACT It is possible to capture and electronically recoginize discrete, or fragmented elements, such as leaves, from nature. Once captured these elements can then be enhanced through layers of additional data. An example of such a tool is one we created called Leaf++. Leaf++ is designed as an ubiquitous, augmented reality, information tool. It functions as a naturally-informed, new "eye" that can be used to look at the natural landscape of our cities, and to see and understand a landscape that is beyond the mere sight and must be understood as a way to reconnect the fragmenting caused by the urbanization of the formerly contiguous landscape. This realm may be referred to as the Third Landscape.[1] Using contemporary toolsets it is possible to re-engage this space.

INTRODUCTION

> *The Third Landscape—an undecided fragment of the Planetary Garden—indicates the sum of the spaces in which man gave up to nature in the evolution of the landscape. It regards urban and rural forgotten places, spaces for transit, industrial wastelands, swamps, moors, bogs, but also the sides of roads, rivers and train tracks. The whole of these forgotten places are reserves. De facto reserves are: unaccessible places, mountain tops, uncultivated places, deserts; Institutional reserves are: national parks, regional parks, "natural reserves."*[2]

Gilles Clément's "Planetary Garden" is one of the most suggestive answers to the mutating definition of urban space. Planetary Garden is to economic and urban globalization what urban gardens were to the cities of the nineteenth century: the latter represented the closed or tightly schemed design of urban architecture and layout, while the former represents the connective, fluid, mutating texture of the globally interconnected city. The Planetary Garden is the garden of the global city. The third landscape is a connective fabric composed of residual spaces that tend to take a liquid state, never preserving shape and resisting governance. Classical preservation or environmental conservation tools that serve as surveillance, protection, or for the creation of borders cannot apply to the Third Landscape without destroying its characteristics, as Clément writes "not property, but space for the future."[3] An idea of space that goes beyond the ideas of landscape as a place for identity, being used as an asset for local societies, and as a strategic tool for memory.

Consider an idea of space that exemplifies, or extends, the possibilities of the contemporary world: a multiplication of narratives; the holistic perception of ecosystems; or the possibilities and richness offered by a disseminated, interstitial, emergent, mutating, temporary, polyphonic environments. These may all support the notion of an end to dualistic approaches. As John Barrell spoke about "the dark side of the landscape" while pointing out the imposition of a point of view of a single social class[4], with Clément we could speak about a "light side," for the Third Landscape is not an exclusive model but an inclusive one, "a shared fragment of a collective consciousness." It is based on a planetary remix (*brassage*) which is at the origin of the current richness of ecosystems.[5] These dynamically mutating spaces embody the presence of multiple agencies forming a city from points of view that are concurrently architectural, political, economic, poetic, activist, and industrial. They present new forms of nature, forms that emerge by instantaneously creating interstitial ecosystems that flow with the story of the city; they describe a realtime syncretic map that develops together with the creation of new areas for residences, industry, commerce, business, culture, and entertainment and they address the death, abandonment and decay of the previous ones. In this manner they form a geography of a mutating city.

Clément talks about the necessity of training our gaze into recognizing and understanding this Third Landscape. This requires a new possibility for vision and knowledge dissemination in urban natural environments, a renewed sense of aesthetics, and a morphed sensibility for the possibilities respecting interaction and communication offered by our surroundings. Our current interaction and interrelation with the natural environment in urban spaces is mainly delegated to an "institutional" definition of borders. This understanding is rather far from the traditional knowledge of the ecosystem and its elements. Inhabitants of contemporary urban spaces continually lose knowledge about their environment as they allow social administrators and commerce to transform the knowledge of a topology, and define it. Globalization and daily routines often force human beings to recognize plants and vegetables only in terms of their use in products that are found in supermarkets, or of the trees and bushes that decorate the sides of our roads. People progressively lose contact with the knowledge about the seasonality and origins of vegetables as they have come to expect any given product at every given time in a supermarket. One study (among many other studies of a similar scope) provided advice to farmers in remote parts of the world encouraging the production of off-season products for export and highlighted this practice as a truly effective marketing strategy based on the documented assumption that consumers want specific products all-year-round.[6] When stepping outside of the supermarkets, however, we see that plants still remain a great unknown to the majority of inhabitants of urban spaces. In cities, plants populate the periphery of our world view, living a life that is mostly aesthetic. They exist without their fellow inhabitants having practically any knowledge about their origins, characteristics, benefits, and roles in the ecosystem. Their essentail character remains largely hidden for the majority of citizens.

LEAF++

As an augmented reality system Leaf++ deploys computer-vision techniques to recognize plants from the structure and nature of their leaves. Leaf++ then augements this through associative digital information, interactive experiences, and generative aesthetic experiences. This allows the application to create a disseminated, ubiquitous, accessible form of interaction with the natural environment. This capability, in turn, yields suggestive, engaging, yet most of all, desirable and accessible contact with an increased awareness about the inhabitants of the natural ecosystem in our surroundings. From such knowledge a new wisdom grows through the augmentative and data collective aspects of Leaf++.

Leaf++ shifts our focus, and allows us to reconsider the way we envision urban landscapes. Through its features of augmented reality, and the layers of additional data it builds an infoscape—an information landscape which is directly and coherently added to our vision with information about their origins, living conditions, characteristics and interactions with our urban/natural ecosystems. Leaf++ does this in a highly accessible way by which a new vision of leaves and plants comes to be seen through a new visual life. Leaf++ also acts as a distributed, dynamic, realtime, emergent geographer of the Third Landscape: each usage triggers a mutation of the map which is shared in realtime by all persons using Leaf++, providing a fluid cartography of the Third Landscape.

Leaf++ allows a new field of vision that is accessible with the new natural gesture: looking at the world through a mobile device. This acts as a new lens on reality; a new vision in which leaves and plants come to visual life as the computer vision system actively searches for them and highlights them, populating our view with information about their origins, living conditions, characteristics and interactions with our urban/natural ecosystems. In this manner Leaf++ acts as a distributed, dynamic, real-time, botonist of the Third Landscape. Each member of the plant kingdom in the urban space triggers a mutation of the map which is shared in realtime by all persons using Leaf++, this, in turn, provides a fluid cartography of the Third Landscape. These new visions reveal a ubiquitous sensorial experience through transforming, morphing, moving images and sounds that create a state of wonder that further connects us to this new visual landscape.

THE PROCESS AND METHOD IN CREATING LEAF++

The Leaf++ project began with an initial briefing; this produced a working definition of the concept. From this conceptual stage choices emerged and experimentation was conducted involving several technologies that could be used to realize the concept. From this point the design and implementation commenced for several prototypes. These permitted an iterative, participatory process to unfold from which the generalization of the best prototypal solutions for an open platform was considered. The usage studies from the prototypes resulted in a decision to create two use cases, one for education purposes and another for artistic performance.

Leaf++ was intended as an augmentation for vision, to increase the level of awareness about the natural environment and to promote the establishment of a collaborative set of practices for the dissemination and communication of knowledge about the ecosystem. Leaf++ also permits the creation of an ubiquitous digital interactive layer upon a natural environmental layer. This could have great utility for education, as well as expression for artistic and performative purposes. Fields such as anthropology, cognitive sciences, biosemiotics, environmental psychology and aesthetics could all find utility in the use of this augmented reality. In addition, the range of disciplinary experiences in geography, geoecology, geobotany, ecology, landscape architecture and planning, particularly where these may converge in the direction of landscape ecology could reveal advantageous usage. The term landscape may yield to these approaches as the definaition of landscape may have multiple dimensions—as reported in Farina:[7]

> *"the total character of a region" (von Humboldt)*

> *"landscapes will deal with their totality as physical, ecological and geographical entities, integrating all natural and human ('caused') patterns and processes … " (Naveh)*

> *"landscape as a heterogeneous land are composed of a cluster of interacting ecosystems that is repeated in similar form throughout" (Forman and Godron)*

> *"a particular configuration of topography, vegetation cover, land use and settlement pattern which delimits some coherence of natural and cultural processes and activities" (Green et al.)*

> *"a piece of land which we perceive comprehensively around us, without looking closely at single components, and which looks familiar to us" (Haber)*

All of these definitions move across several dimensions in which landscape can be described, with the more cognitive-oriented ones (such as Haber's) resulting in broader visions that are able to bypass the concepts that might classically be viable for public administrations to enact their policies and strategies. These newer, or alternative definitions could produce a more fertile humus for creation of a improved description of the planet, including far more expressive and performative possibilities for humanity.

The concept of cognitive landscape, and of its possible "technological interpretations and contaminations" in conjunction with advanced contemporary research in urban anthropology, has been a fertile domain for discussion during the initial phases in which we gave shape to the concept. A cognitive landscape can be thought of as the result of the mental elaboration by every organism of the perceived surroundings.[8]

We decided to apply such technological contaminates respecting the observations found in Farina's analysis of the theory of cognitive landscapes, as well as the mosaic theory within Clément's idea of nomadic observation of a constantly mutating environment, by focusing on the value of being able to recognize and understand the fluid and everchanging natural ecosystem in a process that is inclusive, collaborative, and disseminated. In this mindset, we described a focused series of objectives, which later formed the concept for Leaf++:

- to create a tool for vision or, even more desirably, a new or mediated vision;

- to create an accessible and natural interaction metaphor, as close as possible to the practices to those which we are accustomed to; one which is easily executable by a wide range of persons across cultures, age groups, skills;

- to create an open platform, distributed as documented Open Source software, so that it will, in and of itself, create an active ecosystem of practitioners wishing to use and modify it to enable more practices and possibilities for vision, awareness, understanding, expression and ubiquitous knowledge sharing;

- to create a usable information and interaction layer that is easily hooked onto the elements of the natural environment and that is accessible through mobile devices;

- to create a process which harmoniously conforms with the processes of our vision; just as we interpret what we see geometrically, symbolically, culturally or through our memories, experiences and relationships, Leaf++ should progressively populate our mediated field of vision with aesthetics, information, knowledge, possibilities for relation, understanding and interaction, just as details progressively emerge while we look at things;

- to create an aesthetic, sensorially stimulating, cognitively suggestive experience; one which is able to trigger wonder and emotion, to inspire action and participation, to activate cultures and open dialogues.

Along the lines defined by these objectives the research group set forth in designing the experience which was to be then implemented. The most pressing point turned out to be one regarding the ability to characterize Leaf++ as a "vision." Current Augmented Reality (AR) systems did not completely satisfy us with their interaction metaphors.

The composition of their interfaces relied on movie-generated ideas of what an augmented reality interface should look like: radars, sonars, floating icons, and other visual assets seemed to create videogame-like experiences. While some of these might be usable (and wonderful to look at) they did not match the feel and aesthetics of the "new vision" which we wanted to produce. Our desire was to create a lens, a see-through transparency onto which the additional information layer would visualize in the most natural possible way.

Another of the more pressing characteristics which we wished to research was the bypassing of the limits imposed by GPS: compass and accelerometer driven augmented reality systems. We wished to to create an experience that was strongly based on (computer) vision. Furthermore, the invasiveness of the marker-based versions of AR techniques did not seem to fit in with the goals of the project. One of the objectives which we regarded as being not only strategic, but fundamental in promoting the vision which is defined by the Leaf++ project, was the requirement for the openness of the technologies used and produced in the process. Due to this consideration the research team opted not to use any of the existing commercial (even if free) platforms that are currently available to perform computer vision based AR. We chose to develop our own technology and to release it for open usage to the international scientific and artistic community (the source code of all software used in Leaf++ is currently available on the project's website under a GPL3 license). The production of an open, working platform is, in fact, one of the most rewarding results of the project, for it fully supports the idea of open, accessible knowledge that we desired to enact in the natural ecosystem by engaging the making of Leaf++.

TECHNICAL ASPECTS OF THE LEAF++ PROGRAM

We developed a mobile Augmented Reality (AR) browser that would support the objectives and characterisistics of the Leaf++ project as formerly described. The chosen mobile platform was developed for Apple's iPhone. This decision was based on the advantages of a stable development environment and ease of use. The iPhone also satisfied our requirements for accessibility and usability. Finally, due to the availability of multiple international development groups dealing with computer-vision issues, such as the ones involved in the project, the mobile platform allowed us to establish an effective mutual collaboration. This proved both effective and rewarding during the development of Leaf++.

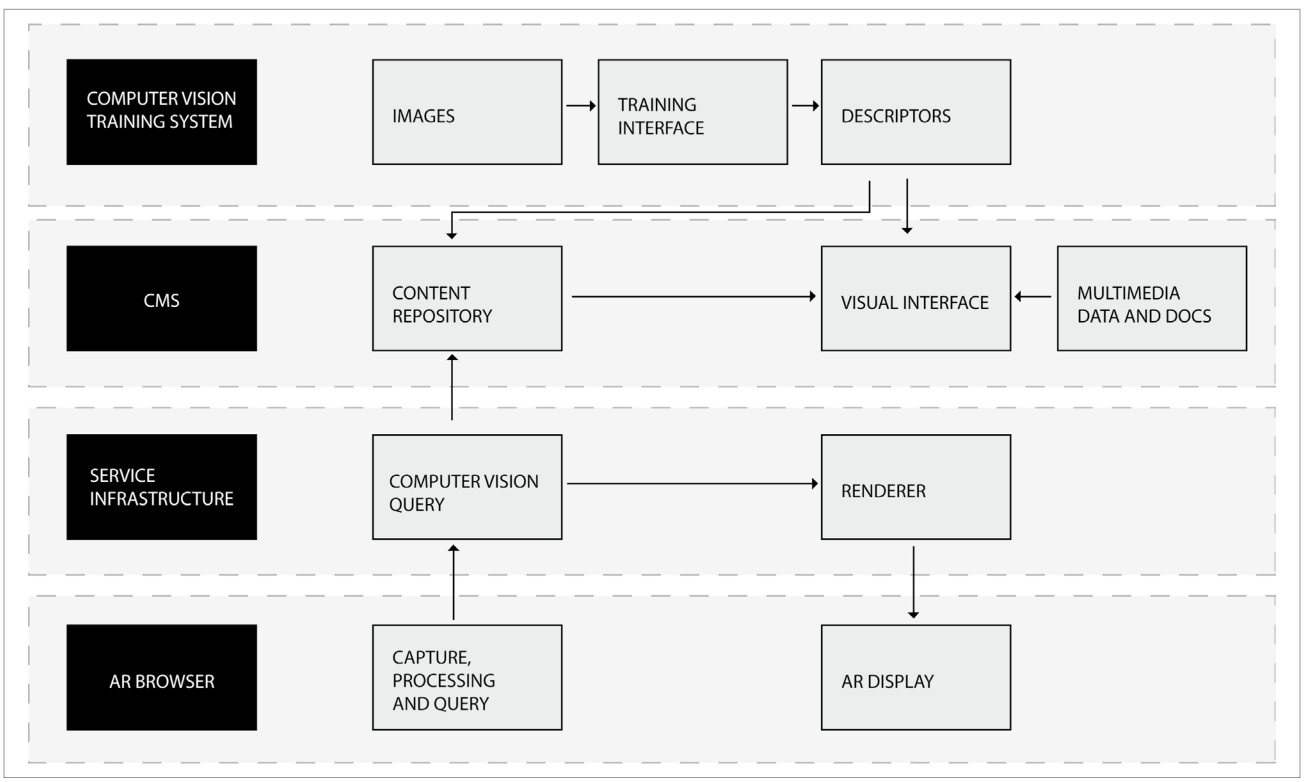

FIGURE 1

The platform created for Leaf++ is composed by the following elements:

- a trainable computer vision module
- a multimedia Content Management System (CMS)
- a service infrastructure

The diagram presented in FIGURE 1 describes the overall architecture. A Computer Vision (CV) module is used to provide image recognition features for the system. The CV module uses Speeded Up Robust Features (SURF) algorithms to identify the various types of leaves. The SURF image detection techniques and descriptors [as described in 8] are used in the system together with a customized version of the optimizations [as described in 9]. These optimizations are integrated with other custom modifications to the basic SURF algorithms—this allows the creation of multi-layer versions of the descriptors—produced by the image recognition software components. The layering of the descriptors is designed to create a distance set of metrics that can be easily applied to the recognition process. Using an optimized b-tree based search process the initial scans of each image benefit from the quick elimination of those leaf image models which are unclear because they are "too far" from the recordig device (this dimension being configurable according to the set of plants which are meant to be recognized). The first layer of the descriptors, implementing a low resolution analysis, performs this very efficiently. With this resolved, the next layer(s) of the descriptors can focus on the identification of more localized characteristics of each model, as these benefit from the previous processing phase. In FIGURE 2 three of these step can be deciphered in sequence. The example shows how the various phases for image recognition (and the respective layers of the descriptors) enable progressively more granular details of the image through a b-tree optimized analysis whose branch decision scheme sequences from one level of detail to the next. In the image, the highlighted points/crosses show the features that are used at a specific level of the descriptor. Thus the b-tree led analysis progresses from level to level, focusing on image areas that are progressively smaller, enabling beneficial granularity. The integrated CV component supports the following process:

- image acquisition
- generation of feature descriptors
- classification and initial configuration of the CMS

A guided procedure allows the user to capture all the images that are required in order to correctly identify the leaves which are to be added to the system. In the next phase of the process an interface is used to navigate the groups of images of each feature and to use them in generating the SURF descriptors that will be used in the end system. Each descriptor uses information captured by the images to create the data that is needed for the realtime image recognition process.[9] An initial version of the descriptor is generated automatically and the user is guided through a series of iterations. This refines the ini-

FIGURE 2

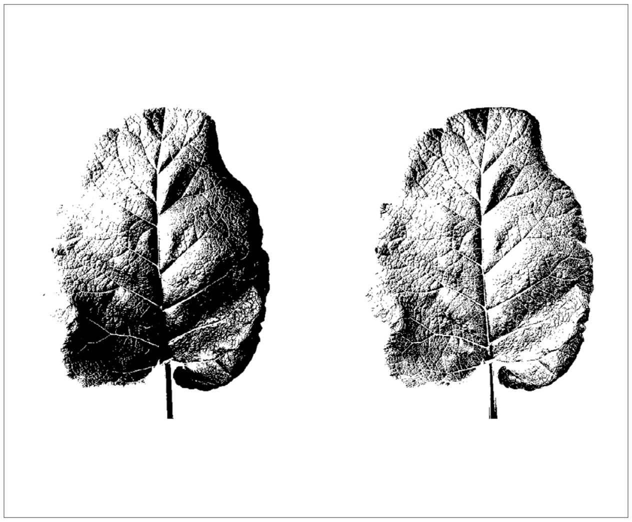

FIGURE 3

tial information, thus generating an increasingly improved descriptor: by iteratively modifying selected parameters through the leaves in front of the camera, the expected results are compared to the exemplary ones, thus identifying the needed modifications to the descriptors.

The progress of these iterations allows fine tuning to the levels of granularity used to proceed through the levels of the descriptors and the refinements that are achieved in the single levels. Images can be replaced by re-uploading them into the processor: this to correct undesired situations in which light conditions, perspectives, or visual obstructions prevent optimization.

There are several optimizations that transform an otherwise "general process" into an "enhanced process" toward the most effective image recognition for leaves. These include: a focus on border/edge enhancement and recognition, and a focus on the symmetries that are typical in leaf shapes. Such parametrized complexity, according to various radiuses and offsets of symmetry, can be accomodated by various leaf shape types. In FIGURE 3 it is possible to see two examples of the results of this process, on a single, detailed (third level) descriptor. On the left of the image, a non-optimized descriptor shows areas both of extreme density in features, and areas of relative emptiness respecting feature identification. On the right, a correctly equalized image allows for the selection of homogeneously distributed feature points, at various levels of granularity (meaning that there are feature points that collaborate in describing visual features of the leaf at different scales, such as borders and veins, down to the smaller texture components that are typical of certain types of leaves). At the conclusion of this part of the process a series of the described multi-layer descriptors are produced, one for each type of leaf that is to be recognized. Each is associated to a series of keywords, establishing a taxonomy whose nodes are now associated to the visual elements of the various types of leaves. This taxonomy is used in the CMS.

The CMS is implemented using a customized version of the Wordpress content management platform under the form of a "customized taxonomy." Although Leaf++ uses a series of completely personalized interfaces these are designed and developed as a complete and integrated set of themes and plugin components compliant with the standards defined by the Wordpress development community. This characteristic allows the achievement of a very important result: the Leaf++ infrastructure is deployable on virtually any Wordpress-powered website, making it really accessible, convenient, and easy to use. Any form of research that could benefit from a tool implementing augmented reality characteristics of the kind inherent within Leaf++, can use the software by simply installing a standard Wordpress CMS and configuring the Leaf++ personalized theme and a series of three plugins. The whole software stack used in the Leaf++ system (including Wordpress and other software components included into the various modules) are distributed under a GPL3 licensing scheme that allows maximum freedom of use for all forms of research, art, and non-profit endeavors.

Using the standard features of the CMS it is, thus, possible to associate multimedia content (videos, sounds, texts, documents, and interactive experiences) to each part of the taxonomy and, therefore, to the visual elements of the types of leaves that have been added to the system. Several "custom posts" definitions are included in the Leaf++ in addition to the Wordpress CMS. Custom posts schemes define content assets that share a specific and fixed format that allows the creation of personalized forms through which users can populate with content. Leaf++ uses a series of these custom post definitions, enabling users to create augmented reality content that are made out of simple text, images, sounds, videos (in a format that is compatible with most smartphones), and 3D objects in the COLLADA format. Dedicated input forms allow users to add these types of content blocks to the various parts of the recognized leaves, associating them to the keywords in the taxonomy and, thus, associating them to the various parts of the leaves to which each is associated.

The service infrastructure is used to amalgamate the system together in order to create the resulting user experience. A series of software components that can be readily integrated into iPhone applications connect to the device's webcam and enact the realtime feature recognition process. When a leaf is recognized, its identification is translated into a series of terms in the custom taxonomy and relevant content is fetched over the network by interrogating the modified Wordpress CMS. The multimedia assets are then progressively presented within the smartphone's viewfinder, with the realtime onscreen position of the leaf. Information is shown on the mobile device using a custom renderer which is built using HTML5 and CSS3 technologies. This allows content to work on all major smartphones that are currently on the international market. It also allows for the production of one, adaptable, version of the interface which will then be deployed to the various types and brands of smartphones, allowing for a wider audience to use the application at a much lower cost of development.

The smartphone interfaces can integrate a custom logic to leverage the information obtained by the service layer to implement specific functions.The first research phase for the Leaf++ project ended with two simple applications: the first dedicated to education and the second to performance arts and generative electronic music.

The education application is shown in FIGURE 4 and FIGURE 5. It is a built for a very basic use case scenario in order to thoroughly test all the features of the platform. It can also be utilized as a complete, documentable example application to be delivered to interested researchers who wish to experiment with this type of augmented reality system. The application recognizes one of the supported plants (there are seven in the example application) as soon as they enter the viewfinder of a smartphone and uses augmented reality to progressively layer the information for that plant as contained in a database, including: scientific name, place of origin, seasonality, interesting characteristics for our health, wellness uses, etcetera. Simultaneously, whenever a plant is detected in an urban space, the user has the ability of marking it as an element of the Third Landscape, thus populating a time-based map that can be collaboratively compiled in order to study the presence and distribution of the Third Landscape across cities and urban agglomerates.

The application dedicated to performance arts generates a multi-media process called "concert for augmented leaves." In this version a set of leaves coming from the surroundings of the venue of the concert is used to trigger the Leaf++ system, causing the application on the smartphone to start, allowing the performer to use these leaves to generate music according to their visual features, border shapes, size, veins, textures. Each of these items—which are identified through the computer vision system of Leaf++—are used as parameters of a generative music software, producing and modifying sounds, filter, notes, and/or sequences that are directly connected with the identified visual features and their position on screen. Therefore, the visual features generate the music while producing the visuals for the concert—in complete synesthesia. After the first part of the concert the audience is invited for a walk in the surroundings of the concert venue. This enables the creation of a walkable, disseminated, augmented reality concert, and in addition, it leverages another feature of the application: the function that takes care of synchronizing and harmonizing the sounds of several Leaf++ systems when they are close together. This is accomplished using Bluetooth technology.

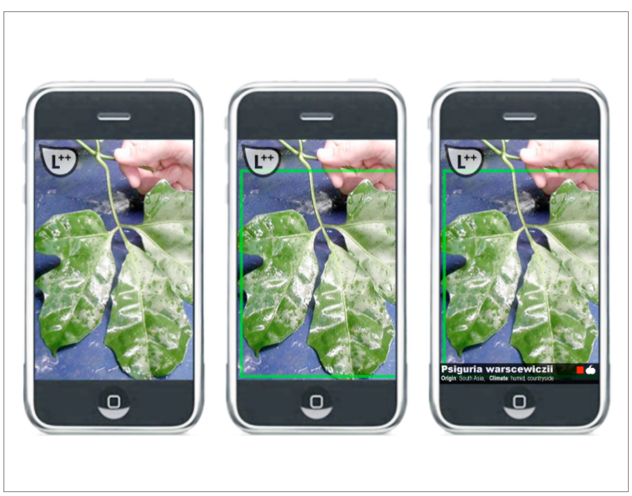

FIGURE 4(TOP)/FIGURE 5(BOTTOM)

BIOGRAPHY

Salvatore Iaconesi is an artist, robotics engineer, hacker, and interaction designer. He teaches Cross Media Design at the Faculty of Architecture at the University of Rome. He is president of FakePress Publishing, an international think-tank exploring the frontiers of publishing together with artists, architects, designers, institutions, and businesses worldwide.

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Cary Yungmee Hendrickson received her MSc. in environmental studies and sustainability science from Lund University. Her research interests revolve around theoretical and empirical intersections of political ecology, the commodification of nature, and global institutions for environmental management. Her doctoral dissertation is focused on multi-scalar linkages between the networks of actors involved in carbon offsets.

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