Garden Variety Pervasive Computing

UNSEEN, a knowledge-sharing experience machine for outdoor public spaces, continuously collects real-time data on plants, insects, and animals through a multicamera vision system. UNSEEN's interpretation and sharing of this data invites visitors to reconsider and question their preconceptions about wildlife.

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Nature interpretation centers are a romantic expression of the desire to understand and experience nature without giving up the comforts of civilization. Advances in digital technologies let us collect and store masses of data about our natural environment, but we are more removed from it than ever. As a society, we find ourselves trading experience-based knowledge for comfort. Interpretation centers attempt to shore up this deficit through visual effects. Following trends in news and entertainment TV, they offer seductive media shows depicting portraits of wildlife busily eating, hunting, cleaning, and so forth—in contrast to the reality where usually nothing much happens.

To address this unsatisfying approach, we wanted to experiment with computationally enhanced alternatives. We aimed to be closer to the object of inquiry, both with our technology and our knowledge design. Thanks to support from the International Garden Festival (see the related sidebar), we found an opportunity to design and build such an experimental space. For us, the public garden offers an interesting conditioning of the natural environment. Midway between untouched, pristine land and controlled construction, public gardens are established forms of colonialized wildlife. Following the Linnaean tradition, their labeled trees and classified plants suggest "known" elements and hold no secrets. Paved paths and directional cues prevent accidental disorientation and exposure to uncontrolled spaces. There is no room for questions.

We chose to challenge this construction with UNSEEN, an active, outdoor computing system embedded in the gardens and capable of operating throughout the summer-long festival, seven days a week, from dawn till dusk. We designed our system to formulate hypotheses on the environment it observed. We aimed to make visitors unfamiliar with life forms they might believe to know. In this article, we describe the conception, implementation, and evaluation of a knowledge-sharing system for outdoor spaces. Like a nature interpretation center, our fully automated, machine vision-based outdoor installation shows visitors interesting facts about the area they are visiting. Unlike such centers, our installation questions factual knowledge and takes interpretive liberties. UNSEEN invites visitors to reconsider their preconceptions about wildlife.

Site design

The site design consisted of nine planting areas with 10 different plants, a rest bench, and an observation post containing three visual displays (see Figure 1). Of these nine areas, we arranged

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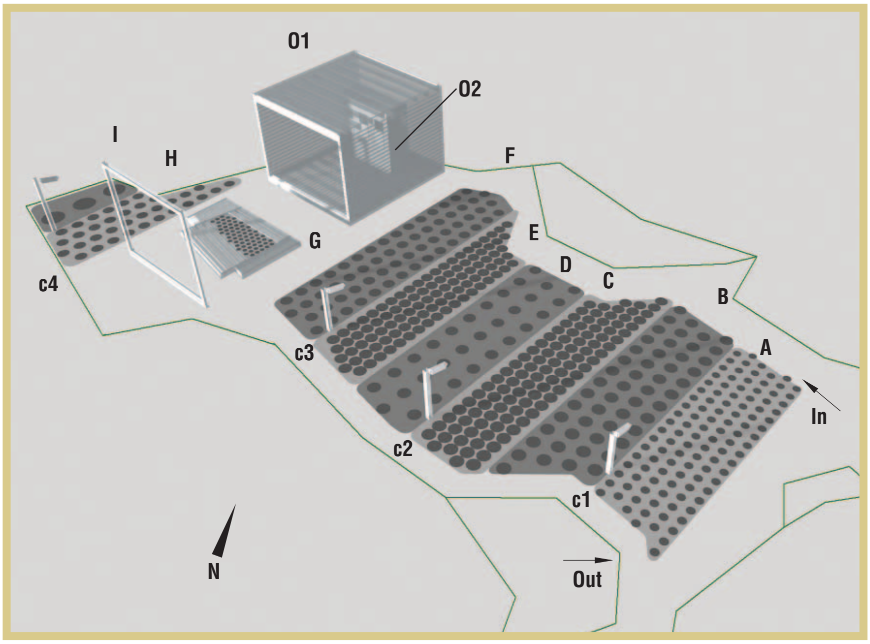


Figure 1. CAD site overview: lowbush blueberry (A), foamflower (B), bluebell (C), wild sarsaparilla (D), wild and garden columbine (E), Canadian burnet (F), Canadian violet (G), alpine cliff fern (H), redosier dogwood (I); cameras 1 to 4 (c1–c4); and the observation post (O1) and electronics box (O2). Arrows indicate the direction of visitor traffic.

eight in parallel strips overseen by a four-camera machine vision system. To reach the observation post, visitors walked by six of the eight strips, which had labels of the plant names.

The plants included lowbush blueberry (*vaccinium angustifolium*), foamflower (*tiarella cordifolia),* bluebell (*campanula rotundifolia*), wild sarsaparilla (*aralia nudicaulis*), wild columbine (*aquilegia canadensis),* garden columbine (*aquilegia vulgaris*), Canadian burnet *(sanguisorba canadensis),* Canadian violet (*viola canadensis*), alpine cliff fern (*woodsia alpina*), and redosier dogwood (*cornus stolonifera*).

These plants are visually unspectacular. We chose them for their biochemical, medicinal, and ethnobotanical properties rather than looks. For example, the indigenous peoples of the Gaspé and other regions harvested sarsaparilla and cooked it into a tasty brew long before its root became the basis for root beer.

Once visitors reached the sixth strip, the observation post (see Figure 2) lures people to take a second look as what seems like a solid wall from a distance proves to be see-through up close. We constructed the structure by placing four-by-fours spaced half an inch apart on a simple timber frame. Inside the observation post, three bright video screens stood triptych-like in front of an open-backed view of pine and bush.

Seeing, knowing, and assuming

UNSEEN had only one form of input: image data. We based our attempt to invite visitors to rethink their expectations about plants and animals on machine vision's ability to deconstruct and rearrange the visual process. Our image analysis procedures queried the image as data for alternate forms of information representation. Because knowing has so much to do with seeing, our invitation to think differently began with methods of seeing differently.

Our system operated in three modes. In the first mode, we synched and checked all four cameras for the highest degree of activity among the plant strips. Here, we evaluated activity numerically as a degree of change in successive images. For example, objects moving across the field of view generate such change—the larger the object, the faster the movement, and the higher degree of change. This simple monitoring procedure can't differentiate between a mouse scurrying through the garden or plant leaves swaying in the wind. Whichever camera registered the highest degree of change temporarily received the computing system's complete attention. The system then displayed the unaltered image stream on all three screens simultaneously in real time. Most visitors noticed the real-time streaming of

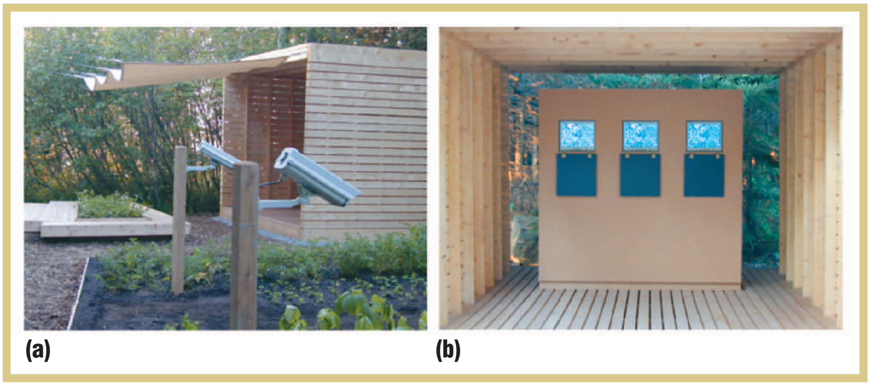


Figure 2. UNSEEN: (a) side view and (b) inside the observation post.

images immediately and compared and questioned their own observations with the image steam. Showing images that are only slightly moving can generate a quiet, soothing effect, and watching things that hardly change draws your attention to the smallest details (see Figure 3a). After a few minutes of streaming such data, the system rechecked its priorities, repeated this process, or moved to the second operation mode.

A variation of this approach showed visitors a cumulative difference image in grayscale. This image slowly intensified as movements under the camera accumulated. This mode of seeing is unique to machines. By using differential images, you can reduce the numeric representation of change to minimal information (Figure 3b). Mapping this to a grayscale representation makes for intuitive information visualization.[1,2]

The second, comparative mode of observing compared the garden's current state to previous states. The system took an image from each garden around 4:30 in the afternoon, when the light is soft, and stored it to disk. Unseen showed the collected images, four per display, in a tiled format over all three screens. This sequence represents the history of the garden in 12 episodes at a glance. Over the course of the summer, the intervals between the selected images increased and the difference between each image grew, but the total number of displayed images remained constant.

The third mode, plant description, aimed to vary plant descriptions over time as a function of growth density and to speculate on the plants' future. We wanted our system to ponder possibilities. We gauged the garden's dynamics with a geometric- and hue-based detection scheme. Unseen used color only to detect flowering. The blossom colors ranged from red to dark blue, purple, and white. Most plants begin to flower in the Gaspé much later than they flower in southern Ontario. This seasonal delay let us perform experiments in our own garden, where we planted many of the selected plants in advance. Our hue detection algorithm included a combination of up to three distinct hues, with the option of excluding other hues. The algorithm mainly took geometric properties from the leaf forms and the arrangement of leaves on the stem. For this, we integrated into our program a commercially available geometry-based model finder. The finder readily detected instances of plants with large leaves, such as the redosier dogwood or the sarsaparilla with this scheme. The plant with the smallest leaves and the smallest flowers, the lowbush blueberry, was the most difficult to detect. Here we used the total plant's geometry and built a general geometric model based on it. For each plant, we built a reference model and updated it daily. This information formed the basis for the text generator (see Figure 4).

The plant models taken at the festival's start acted as points of comparison for successive plant models. We updated the models daily and recorded the differences from the original models. We used this change (Δ plant model) along with the plant density as weighting factors for text creation. We used these weights as topic- and hypothesis-level selectors. From these isolated sentences, the text generator (see Figure 4) assembled a short paragraph. So, the garden's measurable dynamics became the driving force for how Unseen described plants to visitors.

While the Δ plant model was small, Unseen described plants according to standard Linnaean classification, followed by a factual account of measurable properties such as appearance, preferred soil type, size, seed count, and so on (see Figure 5a).

In this regard, our system functioned as an outdoor information kiosk with factual but canned knowledge. However, we programmed the text generator to augment this factual knowledge with increasingly hypothetical statements (see

The International Garden Festival

Located on the Gaspé Peninsula in Grand Métis by the St. Lawrence River in Eastern Québec, the International Garden Festival of Grand Métis hosts an annual international festival of landscape and garden design. Each year, the festival invites a juried group of designers, artists, and architects to conceive and build installations in the gardens. In 2003, Unseen was one of the installations selected. The exhibit began in June, ended in September, and attracted over 90,000 visitors.

(a) (b)

Figure 3. Plant images: still from (a) the real-time image stream and from (b) a cumulative motion map.

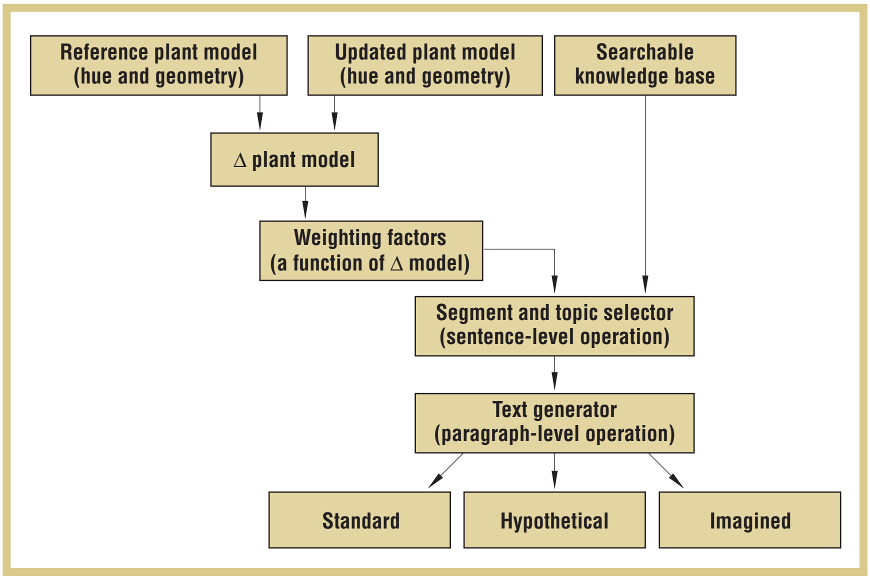


Figure 4. Elements of the text generator.

Figures 5b and 5c) if a given plant was found to have grown sharply in number or to have increased or declined in density compared to the original state.

The database contained hand-compiled material from published articles on all the plants, and some material on animals and insects known to eat or pollinate them. We used excerpts from up to 12 text sources to describe each plant. The sources ranged from scientific journals (such as the *Journal of Ecology, Canadian Journal of Zoology*, and *Communications in Soil Science and Plant Analysis)* to ethnobotany,[3,4] plant lore,[5] and location and niche specifics on the chosen plants.[6] We arranged the resulting database by plant and by topic, so that paragraphs composed from the material are valid isolated statements that when combined were likely to make sense. To enable movement between factual information and pure assumption, we weighted each sentence for its hypothesis potential. The information from the change in plant model acted as an index for this table of weights. An increase in change mapped to a higher index of *hypothesis potential*, shifting the text through standard, hypothetical, and imagined states (see Figure 4).

Arranging and labeling these information components constituted a decisive form of authoring on our part. We chose from the journals those sections and information segments we found most intriguing and pertinent to the project. We chose this as a compromise between the almost impossible task of having the machine create meaningful and interesting material ex nihlio and using prefabricated, canned information. We wanted content to be driven by our authorial control and to let the machine select and arrange information at run time.

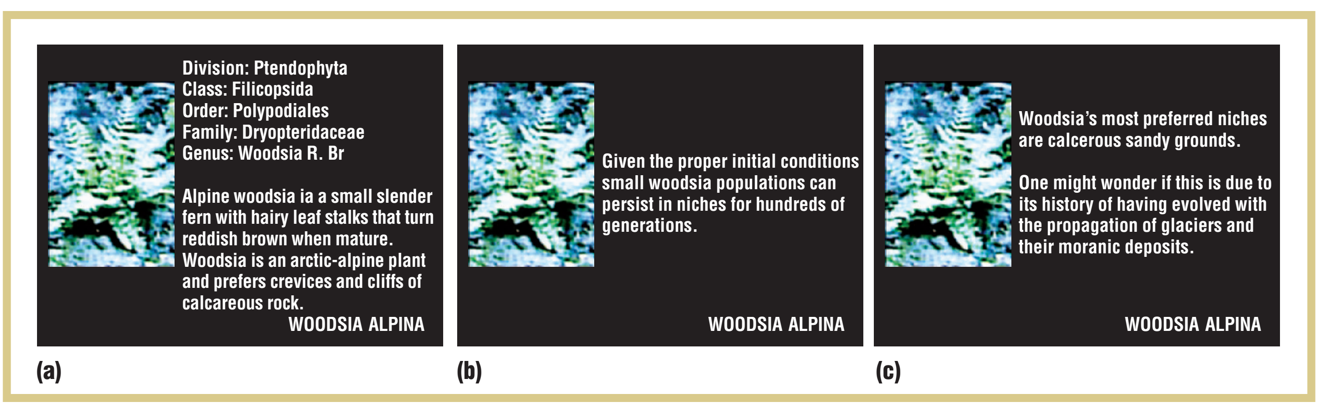
The resulting material is a kind of tentative nature interpretation by many "expert" voices, excited by real-time observation. This is indeed an experiment, albeit with a qualitative outcome. Visitors might find such messages to be confusing or an incentive to refer to other sources or to rely on their own assessment. Who knows best? Whose opinion do we trust?

UNSEEN repeated the three modes of operation in a loop, and every plant in the garden was described, observed, and queried. The program effectively accompanied the interested, patient visitor through the entire garden installation. It was sensitive and reactive as well as patient, collecting data long after busy visitors had moved on to new things.

Design challenges

Working with unstructured spaces presents several levels of engineering and design challenges. Outdoor public environments are not an ideal location for active electronic equipment. Because our system was placed in a large garden in the middle of a forest half a mile from

Figure 5. Text generation for the alpine cliff fern: (a) standard, (b) hypothetical, and (c) imagined.



the nearest power outlet, we had to address a variety of adverse conditions: line voltage fluctuations, strong temperature variations, and high humidity levels. We designed UNSEEN for public access, so we also had to anticipate peak traffic during weekends and allay anxieties about surveillance technologies, while ensuring that we could collect high-quality image material.

We placed all electrical components in a waterproofed box inside the observation post. The architectural structure and a fluttering cloth canopy were designed to minimize the screens' exposure to direct sunlight each day and over the entire season. We controlled temperature and humidity with a strong fan that pulled in cool air from under the construction's wooden floor.

We placed the four weatherproofed cameras between the strips such that each camera could survey two adjacent fields. The cameras were set below eye level and directed downwards. This low, downcast setting made a remarkable difference in how visitors perceived the potentially invasive technology. Unlike surveillance systems that tower over humans and capture their every act, this system had no interest in surveilling people and conveyed this to the public by its posture, in a machine-body language that could be universally understood. Indeed, people are never seen on the captured images; the field of view purposely excludes them.

To ensure robust operation from mid June to mid September, we let our system "rest" after normal business hours. An external timer synchronized with the computer's clock shut down the cameras and displays once the software stopped requesting image material. This artificial custodian scheme let us limit operating times to the visiting hours without intervention from service personnel. UNSEEN saved parameter settings and select image material to disk, and a system restart in the middle of the night ensured that any small, unnoticed memory leaks wouldn't accumulate and cause system-critical failure levels. Thanks to this conservative approach, we experienced (to our own surprise) no down time once we calibrated and tested the system.

Qualitative evaluation

Many visitors voiced impressions of the installation. Some would have enjoyed an online component to the installation, so they could continue watching the plants from their homes. Some dedicated aficionados of horticulture visited the gardens multiple times over the course of the summer. Hence, a convenient and efficient form of revisiting the site virtually might appear useful. In our view, this is a null option. The last thing we want is to replace the actual visit with a virtual one (see the "Related Work" sidebar). For us, designing this site included making explicit choices about what technology shouldn't do. We put clear limitations on this pervasive system's pervasiveness. We believe this will become an integral component of system design, especially as people in the future increasingly ask for appropriate forms of computationally enhanced experiences.[7]

For many people, visual displays imply immediate return values; our system asked for a certain amount of patience from the visitors. It took about 20 minutes for the four cameras to take a full pass through the fields of plants. But, not surprisingly, visit durations varied greatly, ranging from less than five minutes—barely enough time to walk through the garden—to more than 30 minutes. Some reported more than one return visit to see how our system would react to growth. Others expressed the desire to do so at some point. As far as we know, visit duration was a function of age and background, but not gender. On the hottest and most humid days, the visits were generally shorter. Time is a delicate design factor in large-scale public work. Calm and patient computing[8] requires calm and patient people.

Our audience included international as well as regional visitors. The Gaspé is part of francophone Canada, but people are competent in both French and English. However, some regional visitors took issue with the fact that the system didn't translate the results from the text generator into French. When working with computational media, using English as the official language often goes unchecked. We failed to anticipate the potential for English to have a negative connotation in this setting. We also failed to anticipate the desire, by mostly young male visitors, for touch command and control. Many younger men were compelled to attempt to alter whichever settings were visible on the display consoles. Women and older visitors seemed to have no problem refraining from this impulse.

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In the future, we expect this type of installation and its logic to become more common. Deploying AI and machine vision within the domain of cultural studies can benefit both fields. Philip Agre,[9] Phoebe Sengers,[10] and others have made a strong case for integrating cultural studies into the practice of knowledge representation and management (see also "Culturally Embedded Computing" by Sengers and her col-

Related Work

Designing and mixing the real world with mediated information has a history within human-computer interaction.[1] Also, deploying computational tools in outdoor environments is nothing new. Autonomous-robotics researchers have been doing this for decades. More recently, HCI researchers have experimented with adaptive technologies in outdoor settings for educational purposes.[2,3] The Ambient Woods Project demonstrates this type of investigation.[4]

Our work differs from these approaches in many ways. Here, place is paramount. We'd like to find an effective, computational way to meaningfully[5] mediate real-space experience[6] without replacing the source of the experience. The mediation we've devised should lead the visitor to reassess the original experience, not its replacement. We wish to avoid the tradition of learning botany from books.[7] Our system isn't educational, and its target audience is adult. The information our system displays could be confusing. Toward summer's end, for example, the text generator created text beyond factuality. Our system has at its disposal factual knowledge and the patience to continuously observe and self modify, but its results are hypotheses. Visitors must decide for themselves where facts end and interpretation begins. Our machine is an instigator for debate.

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leagues in this issue). Our effort belongs in this vein of work and carries it into the outdoors, querying perception modalities and pondering the automation of decision making. In the end, we make no final claims: important things remain unsaid, essential things remain unseen.

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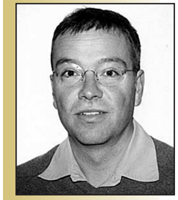

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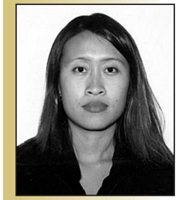

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