Future Gardening System : Smart Garden

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Future Gardening System ― Smart Garden

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To enhance gardening in the future, we have developed an advanced gardening support system called the Smart Garden (SG). To support decisions about what to plant where, SG uses sensors to collect data in the real world that it then plots in a virtual world. Various models then forecast outcomes. Users carry out actions based on these forecasts and evaluate the results. SG uses augmented reality (AR) technology to allow users to view virtual objects superimposed on the real world. This use of computer graphics allows growers to understand the outcomes of their decisions intuitively, while SG records their actions. This paper explains the applications of AR technology in SG.

Key words: augmented reality, computer graphics, gardening, simulation

Introduction

The goal of our research is to build an advanced gardening support system called the Smart Garden (SG). SG supports gardeners in making planting decisions. With increasing numbers of retired people in Japan and increasing interest in healthy eating, home gardening is becoming more and more popular. However, it is difficult for beginners to plan gardens because of the wide range of factors to consider, such as soil, weather, climate, and pests. SG supports decisions about what to plant where with data collected by sensors and organized in a database. The concept of SG is based on precision agriculture, which uses information technology to bring together data from multiple sources to support decisions associated with crop production (National Research Council, 1997).

SG uses sensors to collect data in the real world that it then plots in a virtual world (Fig. 1). Various models then forecast possible fertilizer needs, pest control needs, and yields. Growers carry out actions based on the forecasts and evaluate the results.

SG allows growers to set their own goals. Growers might pursue yield, or particular vegetables, or a mix of flowers, herbs, and vegetables, or a balance of fragrant and beautiful plants. SG uses computer models to forecast the outcomes of management decisions, and the technology of augmented reality (AR) to show the grower the predicted results, as grower feedback is critical.

Augmented reality

Unlike virtual reality (VR), which completely immerses a user inside a synthetic world to the exclusion of the real world, AR superimposes virtual objects on the real world, augmenting reality (Fig. 2), rather than replacing it (Azuma, 1997). AR thus allows interaction in real time and in 3D (Azuma, 1997), using information produced by computers to augment information in the real world. AR is a specific example of what Brooks (1996) called intelligent amplification, using the computer to make a task easier. Several studies have investigated applications of AR systems. Rekimoto and Nagano (1995) proposed a device that can recognize a user's situation by detecting color-coded identifiers in the real world and overlay information by computer graphics (CG). Lievin and Keeve (2001) proposed a surgical simulator that overlays a 3D image of a patient's organs obtained by medical imaging within a head-mounted display (HMD) over the patient, making it possible to operate with precision in 3D. This simulator could also be used in surgical training. AR systems can also be used in manufacturing to superimpose virtual parts on real

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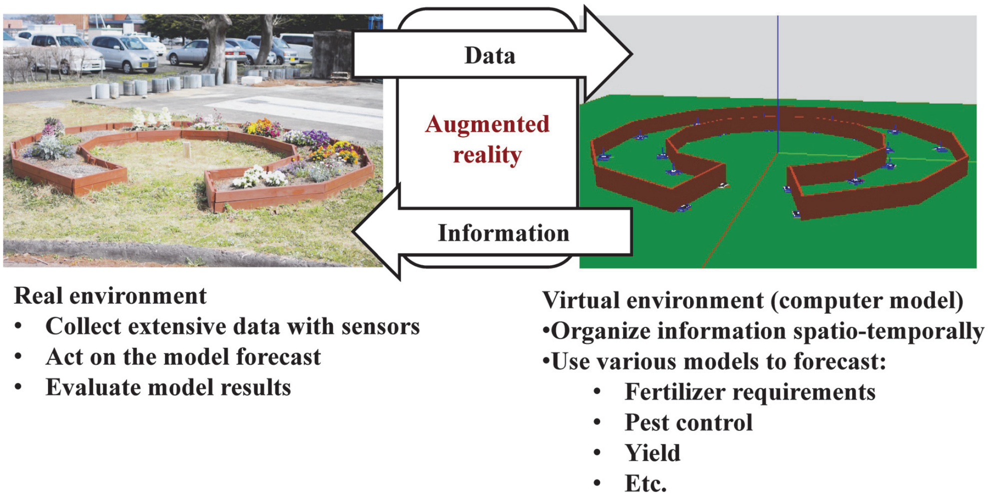

Fig. 1. Smart Garden concept: estimation by image analysis. Various models then forecast possible fertilizer needs, pest control needs, and yields.

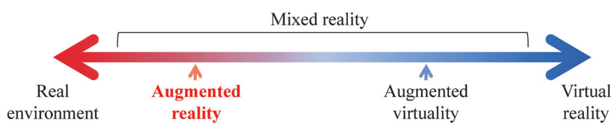

Fig. 2. Milgram's reality–virtuality continuum.

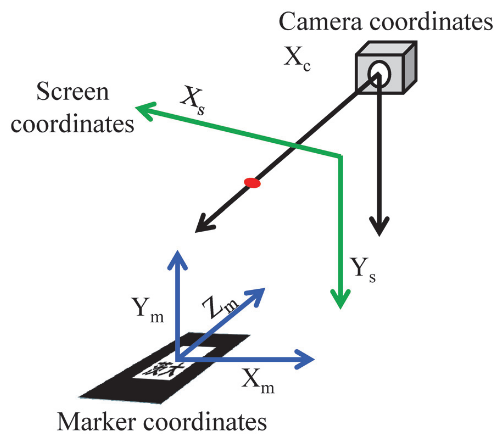

Fig. 3. The relationship among marker coordinates, camera coordinates, and screen coordinates is calculated by image analysis.

assemblies (Reinhart and Patron, 2003).

AR can also augment planting operations by freeing up the hands to work instead of searching for information. HMDs in AR could allow growers to gather information while they are working and to display useful information depending on the context.

Accurate monitoring and recording of actions

To be useful, SG needs to monitor and record actions automatically. GPS (Global Positioning System) mapping is suitable for farming (e.g., Matsuo *et al*., 2011), but its typical error of a few meters makes it unsuitable for gardening. RFID (radio frequency identification) tags are very precise (Nanseki *et al.*, 2007; Fukatsu and Nanseki, 2009), but can be used only within about 200 mm (Fukatsu and Nanseki, 2009). For SG, we adopted the ARToolKit, which relies on fiducial markers to calculate the position and orientation of a camera worn on the head of a grower, and thus the grower's viewpoint.

ARToolKit is a software library supplied for building AR applications (Kato and Billinghurst, 1999; Kato *et al*., ARToolKit homepage). It uses computer vision algorithms to calculate the camera position and orientation relative to fiducial markers in real time. We used the "NyARToolkit for Processing" library (NyARToolKit project), which is based on ARToolKit, within the Processing programming language (Processing.org), which is designed for creating computer art. The language has many functions specialized for visual expression and interaction, and allows images to be controlled readily and intuitively. Each fiducial marker (Fig. 3) is a square black frame with a unique symbol inside, which makes it possible to differentiate it from all others. To track the user's viewpoint (camera position and orientation), SG identifies each fiducial marker in the image captured by the camera and calculates the positions and orientations of the markers relative to the camera. The unique symbol is matched to templates and identified. The position information is then used to render virtual objects in the image.

Test garden

We built a test garden on the Ami campus of Ibaraki University, Japan (36.035993°N, 140.21488°E). The C-shaped garden has 11 compartments with plants growing (Fig. 4). Points on the garden are marked with 24 unique fiducial markers.

Guidance for planting using augmented reality

As an example of how SG can instruct beginners, Figure 5 shows guidance on planting seedlings. The yellow volume indicates a ridge that should be prepared before planting, and the circles show where the seedlings should be planted. The mottled volume shows the ground, and the brown volume below it indicates where basal fertilizer should be applied.

Virtual plants overlaid on the garden

Figure 6 shows a virtual tomato plant overlaid on a real image. The grower can compare the features of the virtual and real plants.

Identification of camera position and viewpoint by SG

To evaluate the performance of SG, one of us walked slowly around the test garden holding a tablet PC with a camera (Acer Iconia Tab W500), looking at each compartment through the camera. The experiment was conducted at 14:00 on 30 January 2013, a sunny day. SG calculated the camera positions and viewpoints (Fig. 7). In most cases, SG could detect the

Fig. 4. The test garden with markers.

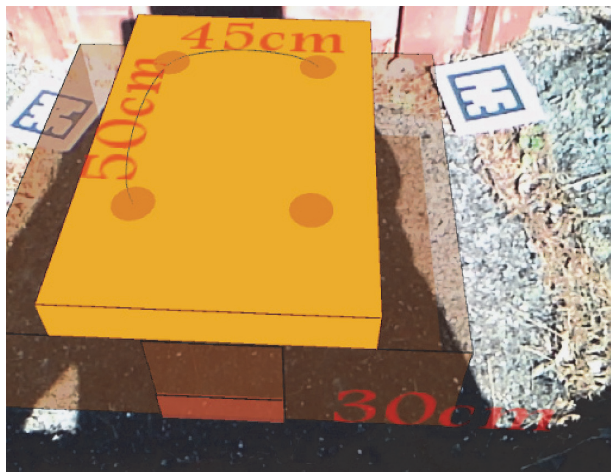

Fig. 5. Computer graphic of planting instructions.

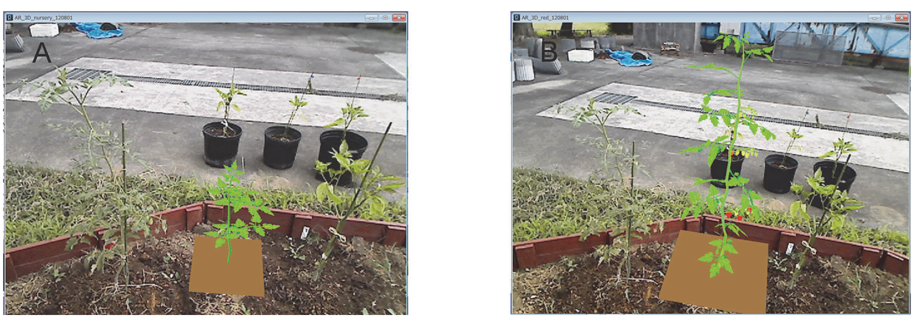

Fig. 6. Virtual plants overlaid on a real-time image. A) CG in the image represents a young tomato plant; B) CG in the image represents a grown tomato plant.

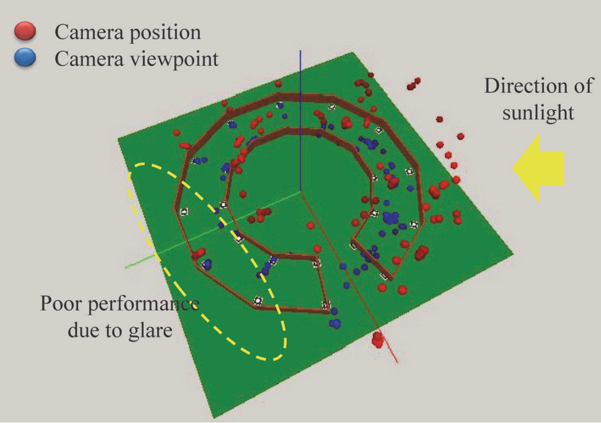

Fig. 7. Recorded camera positions and viewpoints.

fiducial markers well. However, when the camera faced into the sunlight (yellow arrow), SG could detect only a few markers (within the yellow dashed ellipse).

Conclusions

The Smart Garden project is still at the early stage. Our next task is to install environmental sensors with wireless reporting. SG is intended to be affordable and easy to use. Future development will incorporate the input of researchers, engineers, and designers in various fields.

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