PLANTS

PLANTS

Please help yourself to a leaflet

RESEARCH ACADEMIC COMPUTER TECHNOLOGY INSTITUTE

CTI

eden project

Tyndall National Institute

Please help yourself to a leaflet

I have water issues!

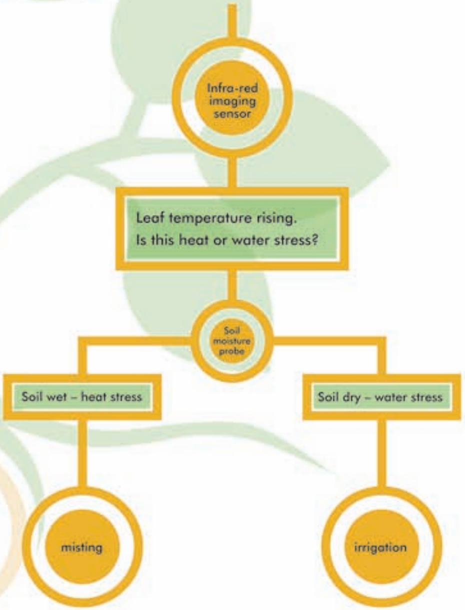
Making Sense of PLANTS

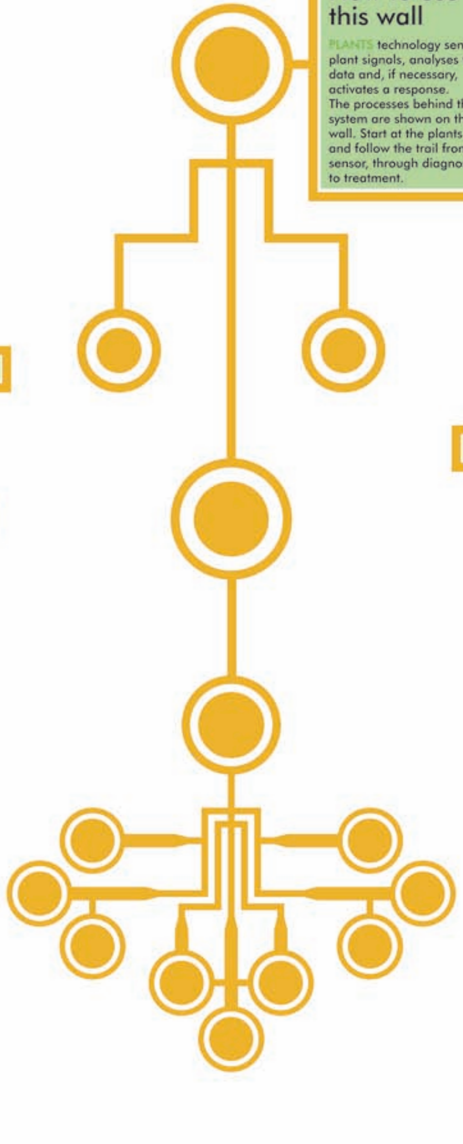
How healthy are these plants?

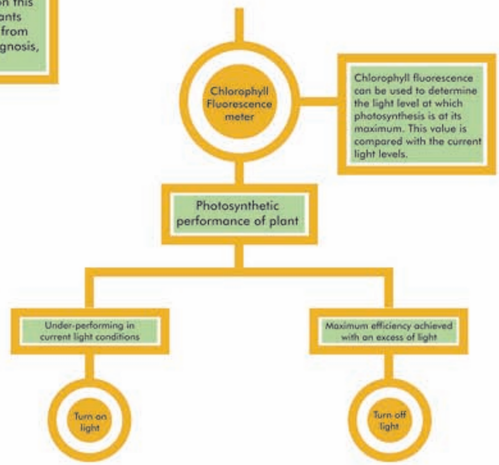
Am I getting enough light?

How to use this wall

PLANTS technology senses plant signals, analyses the data and, if necessary, activates a response. The processes behind the system are shown on this wall. Start at the plants and follow the trail from sensor, through diagnosis, to treatment.







Do I need a nitrogen fix?

Making Sense of PLANTS

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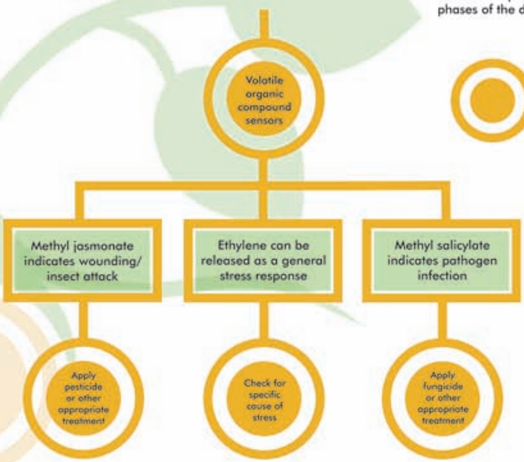
Am I wounded or infected?

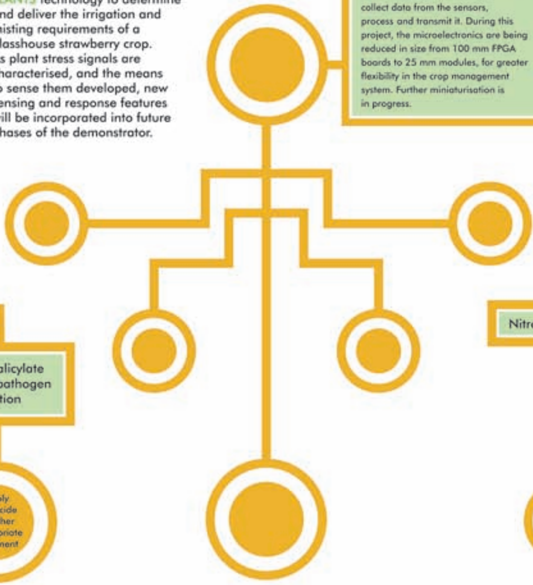
PLANTS technology

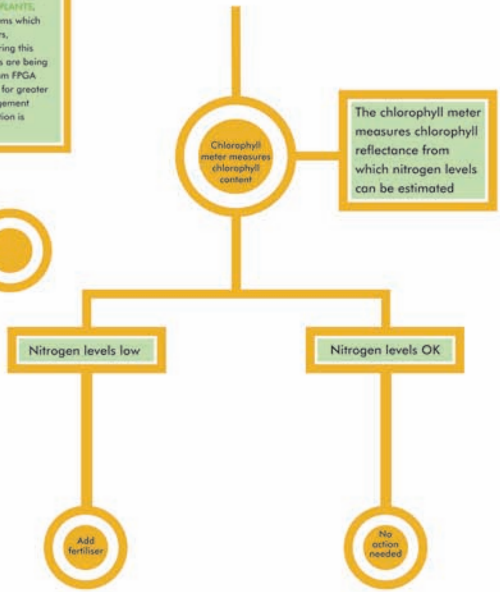
The PLANTS project has developed demonstrator models which show the new technology in operation. The current demonstrator uses PLANTS technology to determine and deliver the irrigation and misting requirements of a glasshouse strawberry crop. As plant stress signals are characterised, and the means to sense them developed, new sensing and response features will be incorporated into future phases of the demonstrator.

Microelectronics in PLANTS

The modules shown in the centre of the wall form a key part of PLANTS. They are technology platforms which collect data from the sensors, process and transmit it. During this project, the microelectronics are being reduced in size from 100 mm FPGA boards to 25 mm modules, for greater flexibility in the crop management system. Further miniaturisation is in progress.







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This project is funded by the European Community under the 'Information Society Technologies' Programme (IST-2001-38900).

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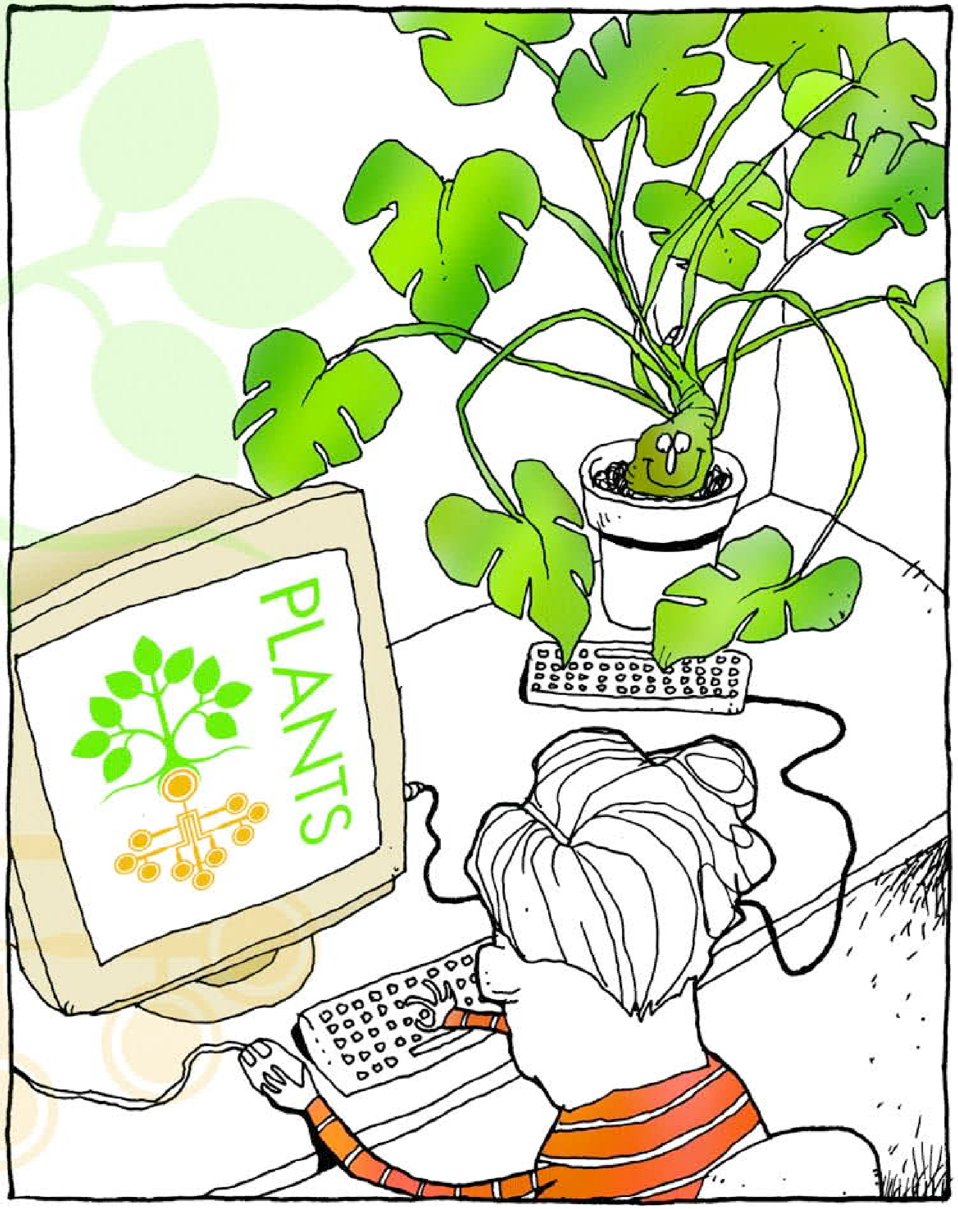


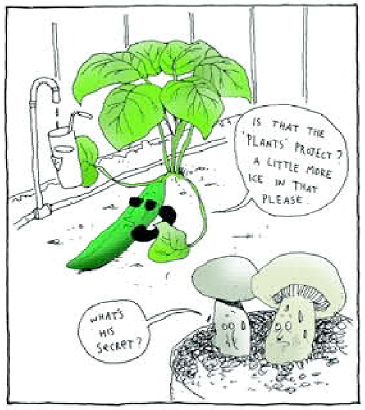
PLANTS PROJECT UPDATE

Introduction

The PLANTS project is developing a novel technology that will enable plants to control their own environment. PLANTS is an interdisciplinary project incorporating plant science, microelectronics, software design and integration and science communication.

Collaborating in PLANTS are Tyndall National Institute (Ireland), Computer Technology Institute (Greece), Eden Project (UK), Department of Zoology, Ecology and Plant Science, University College Cork (Ireland).

PLANTS is funded by the European Union's Fifth Framework Programme under its Information Society Technologies programme (IST-2001-38900).

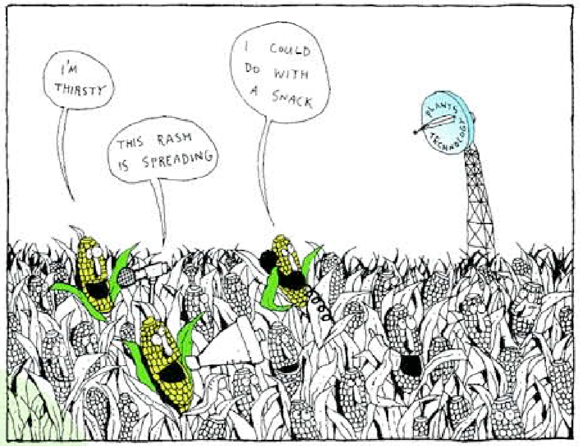


The Project

PLANTS is a three-year research project devising a technology that automatically responds to a plant's needs.

Plants sense and respond to the environment around them. A plant's early response to a stressful situation, such as drought, nutrient deficiency, undesirable light conditions, insect or disease attack can be very subtle; for example, a slight temperature change or reduced chlorophyll content.

The PLANTS project uses sensors to detect plant signals, and microelectronic modules to collect and transmit information. Bespoke computer software interprets the data from the sensors and activates the desired adjustment to the plant's environment. In this way the plant's signals trigger the appropriate treatment.



The Goal

PLANTS aims to optimise the efficiency and productivity of plant growth. An array of sensors positioned around the crop detects subtle plant signals and uses these as the basis for precision applications of water, pesticides or fertilisers. The three-way communication between plants, people and objects will be achieved by a miniaturised wireless system which will be robust and user-friendly. By delivering resources when and where they are needed, the PLANTS system seeks to minimise their wastage and the environmental and human health damage their over-use may cause.

Showcase

As the PLANTS technology is developed it is being deployed to operate in a glasshouse crop demonstrator as a showcase for this state-of-the-art technology.
Elements of PLANTS technology will be displayed in workshops and exhibitions, and the final demonstrator will be the focus of a technical workshop at the Eden Project Nursery in 2006. Principles of this new technology are explained in public workshops at the Eden Project, on the PLANTS website (www.edenproject.com/PLANTS) and from 2006 in the PLANTS exhibit at the Eden Project.

The Software: ePlantOS

PLANTS software, **ePlantOS**, enables plants to communicate with other components of the PLANTS system by converting their botanical signals (detected by sensors) to digital signals, and then into actions.

A crop management system presents a complex, heterogeneous scenario as it includes: living, growing, developing plants; treatment systems, such as irrigation, misting, lighting; communications tools, for example computers, Personal Digital Assistants, mobile phones, as well as people and external sources of information (e.g. weather stations, crop disease prediction services).

The **ePlantOS** software system can be envisaged as rather like a 'parallel universe' in which each physical entity of the crop set-up has a 'digital self'. So, for example, a plant becomes an 'ePlant' by taking on a technological layer. Pumps, lights etc. are similarly represented as 'eGadgets'.

The services/properties of each item/plant are captured in a software abstraction called a 'plug'. Thus each physical element of the crop has a digital self with its own individual 'plug' of characteristics. Plug-plug communication is achieved by setting a 'synapse' – a virtual channel for data exchange between the two. **ePlantOS** is a middleware software layer that manages the network interactions of the system to link up components into a virtual mixed society of plants, people and gadgets called a 'bioGadgetWorld'.

Decisions (e.g. whether to irrigate) are based on the 'ontology', a directory of rules and definitions about plant parameters and characteristics, the core of which is designed to fit the limited memory capacity of ePlants and eGadgets. A higher-level ontology elaborates on the core.

The user interface is designed to be logical and straight-forward. Flexibility is built-in to the system such that the user builds their own bioGadgetWorlds of interacting elements (using BioGW Editor) and is able to edit the underlying rules ontology through SLADA (Supervisor Logic and Data Acquisition Tool).

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Sensor Systems

PLANTS technology operates according to the following procedure: plant signals are detected by sensors and converted to digital signals interpreted by software. Activation of actuators (e.g. irrigation pumps) delivers a physical response to the initial plant signal.

Extreme plant stress is usually revealed by dramatic, visible symptoms, such as wilting, leaf scorch or discolouration, pest and disease damage. Early plant stress signals may be subtle. It is these early signals that PLANTS aims to detect.

Sensor technology platforms for use in distributed sensor systems are being developed. Currently the sensors deployed in the PLANTS system are commercial-off-the-shelf sensors chosen for their sensitivity, reliability, size, accuracy, cost, robustness, speed of response and potential compatibility with the ePlantOS software. Sensors which can be placed around rather than on the crop are preferable.

A key aim is to miniaturise the electronics used in association with the sensors. The PLANTS system began using 100mm Field Programmable Gate Array (FPGA) boards, which can be commanded to collect and transmit data from sensors. Currently new packaging technologies to miniaturise the computing hardware are being developed. Progress in this area will lead to greater flexibility in the crop management system. Also, 25mm modules are cheaper to produce than the 100mm FPGA boards. Whilst they contain less processing power, they are battery-operated and wireless and capable of communicating over distances of greater than 10m. Further miniaturisation is in progress.

Sensor networks

In PLANTS, plant signals are detected using an array of sensors and converted into digital impulses through the ePlantOS middleware, allowing the plant to communicate directly with artefacts. Plant signals are characterised and the threshold levels for action to combat plant stress are determined. Some of the plant signals PLANTS aims to detect are detailed here:

(courtesy of Prof. H.G. Jones, Dundee University, UK)

Temperature signals

Plants transpire - a process which draws water through the plant that eventually evaporates from the leaf surface, cooling the plant. Temperature rise within a leaf can signify leaf pores (stomata) have been shut, preventing transpiration because there is little water available to the plant. Plant canopy temperature can be assessed by thermistors placed on the leaves, or remotely, by infra-red imaging.

Chlorophyll fluorescence

The light absorbed by a chlorophyll molecule raises electrons within it to an excited state. On returning to the ground state, a small amount of the excitation energy is emitted as red fluorescence. Chlorophyll fluorescence measurements provide information on photosynthetic efficiency and the stress condition such as photo-oxidative stress, drought and salinity stress. This method is dependent on the proximal sensing of fluorescence emissions following modulated light pulses.

Leaf gaseous signals

Plants emit a range of volatile organic chemicals with cocktails of these gases relating to the stress response. The composition of the gases released from the leaves can be used to identify the type of stress experienced by the plant.

Environmental signals

Environmental sensors, including light meters, soil moisture sensors and environmental temperature sensors, are used to enable characterisation and analysis of the data from plant-specific sensors.

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Agricultural monitoring

PLANTS researches a new way of managing agriculture towards greater efficiency. Agricultural inputs have increased dramatically over the past century to improve yields. A number of current systems and recent developments offer opportunities for alternative inputs or reduced and/or more precise delivery of inputs.

Integrated approaches use networked weather forecasting in combination with chemical application and gene deployment strategies (which are designed to protect and retain pest and disease resistance qualities inherent to the crop).

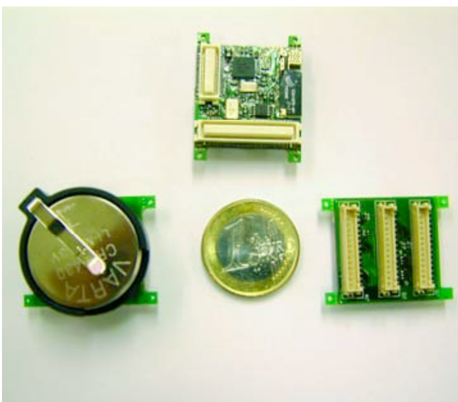
Organic farming represents one solution against excess farm chemical inputs. Though this sector is growing fast, organic farming is only carried out on around 3% of the agricultural area in Europe.

Genetic engineering offers some solutions but there are concerns over this technology. Globally, GM crops are grown on 18% of total land under cultivation.

Alternative inputs include the use of biological rather than chemical control of pests and diseases and development of elicitor sprays, which are able to trigger the plant's own defence mechanisms.

Crop monitoring systems to determine the timing and level of inputs can rely heavily on measuring the environmental conditions around the plant. More recently monitoring has started to focus on the plants and precision delivery of inputs to treat issues that the sensing system detects.

Remote sensing analyses the spectral emissions of crops. It detects between - and within - field variation in crop type, growth and yield prediction. Using remote sensing to detect water stress permits restriction of irrigation to a defined area. Limitations of this technology are that it is expensive, may not provide the data in real-time or be sensitive enough for early detection of disease.



Real-time data can be achieved with ***proximal sensing*** which monitors plant parameters such as temperature and chlorophyll fluorescence. This type of sensing is being used in the PLANTS project to develop a precision agricultural system to deliver inputs in response to a plant's needs.

Throughout the project, PLANTS is producing demonstrator models which integrate an increasing range of sensors to build the capacity of the system. In the first demonstrator, chlorophyll fluorescence data is used to trigger adjustments in light levels over the plant. The second demonstrator is being developed in phases and focuses on controlling irrigation through monitoring of leaf temperature by infra-red imaging.

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