EverGreen

Intelligent Watering System

RMIT University, Australia

Preserving our next generation's future

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1.0 Abstract

This world's natural resources are among our most precious assets. The conservation and preservation of these resources will largely dictate the quality of life that future generations will experience. The availability of water, the most vital natural resource, has been in steady decline throughout most parts of Australia. Serious rainfall deficiencies stretch across vast regions of the country [1], particularly in the densely populated south-eastern regions. Some major cities are recording water storage levels as low as 25% [2] of total capacity after many years of drought. As a result there is a heightened concern regarding the preservation of water and a general receptivity towards new methods of saving water.

EverGreen is an intelligent watering system designed to help address the need to conserve water in a manner which produces cost savings to the user while simultaneously benefiting the community as a whole. It achieves this by calculating and deistributing the optimum volume of water needed to keep a garden/crop healthy, at the most efficient time. Recent studies by Australian water authorities have demonstrated that households with gardens consume almost double the amount of water of households without gardens[3]. Households that install the EverGreen system will notice an immediate reduction in the amount of water that they consume resulting in a substantially reduced water bill, while ensuring that their gardens/crops remain healthy and vibrant. Furthermore they will gain satisfaction from the knowledge that they are contributing positively to help preserve our dwindling water supply.

EverGreen is an intelligent system that communicates with local weather authorities to determine how much rain has recently fallen in the area and to take into consideration near future predictions of rainfall. Using this information, EverGreen calculates the optimum volume of water to dispense into a garden/crop factoring in the soil type, area of coverage, and plant species present. EverGreen then controls the watering process, interfacing with the physical watering system to control the release of water while monitoring flow such that it is able to shut down the watering system when the appropriate amount of water has been released.

Reliability and usability are two driving principles behind the design of the EverGreen system. Research has shown that users would not be willing to spend an inordinate amount of time configuring a watering system and ensuring it works as intended. As a result EverGreen has been designed to operate independent of user interaction after the initial setup. Several redundancy features have been built into the system to ensure appropriate operation in the event of unexpected circumstances. The initial setup process itself has been designed from the perspective of users who are not technologically savvy, guaranteeing a streamlined and intuitive process.

The potential savings in water from the use of EverGreen are substantial. While the need for EverGreen in the Australian market is obvious, and the benefits considerable, the use of EverGreen is also beneficial in other countries that value the preservation of our natural resources.

2.0 System Overview

2.1 System Components

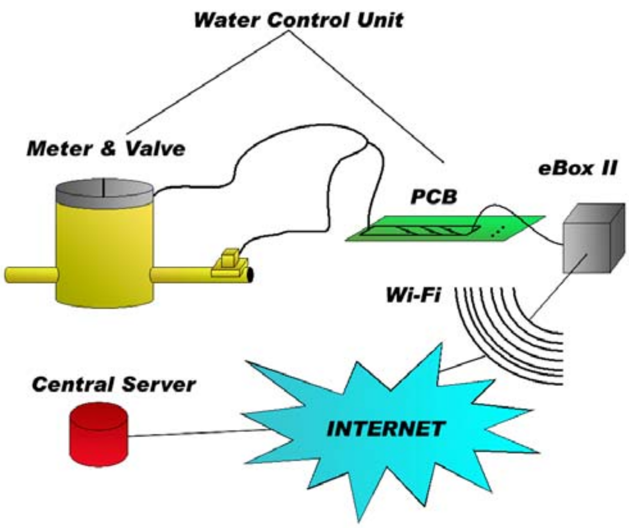
EverGreen has been designed to integrate into a household's current watering system ensuring that there is minimal need for additional plumbing or piping. The system is comprised of the following components:

eBoxII: The hardware package housing the EverGreen System Controller and providing connectivity to the Water Control Unit and the Central Server. This unit runs a customised Windows CE image.

Water Control Unit: The controller to interface with the physical watering infrastructure ensuring that water valves are opened when necessary and flow information is relayed back to the EverGreen System Controller.

EverGreen System Controller: The software residing on the eBoxII which controls the communication, calculation, and configuration needed to operate the EverGreen system.

Central Server: Primarily a means of guaranteeing resilience in the unlikely event of an unexpected catastrophic failure of an EverGreen device.



System Overview

2.2 Innovation

Whist there are some existing water consvering systems in the market, varying in complexity, EverGreen differs greatly from these. EverGreen offers substantial benefits over their limited feature lists, such that it could be considered in another league of watering systems altogether. Many other systems which come close to rivalling EverGreen make use of a distributed moisture sensor system. This system allows them to measure how much water to dispense based on the level of moisture in the ground. The trade off in using such a system is a greatly increased cost of setup. The hardware cost of a system incorporating moisture sensors far exceeds the cost of EverGreen. Furthermore, such a system has no ability to take into account near-present future rainfall predictions, limiting its accuracy.

EverGreen incorporates several innovative features that further contribute towards its ability to provide social benefit, differentiating it from other systems. EverGreen utilises the measurements of highly sophisticated weather and environment sensing technologies, by accessing the Bureau of Meteorology through an internet connection. The accuracy of the data obtained by this technology far exceeds the accuracy offered by measuring devices that could be incorporated into the system at a reasonable price.

Several redundancy features are incorporated into EverGreen, enabling the system to act in an appropriate manner despite the failure of certain key components. Furthermore, EverGreen can be remotely configured and monitored making it ideal for installation at premises where there is no constant human presence, such as holiday houses. Finally, the accuracy of EverGreen far exceeds that of most other systems as it dispenses water based on the measured volume of water passing through device, rather than on the time that the device is active. This removes the uncertainty of varying water pressure determining how much water is actually being distributed.

2.3 Commercial Feasibility

EverGreen is a commercially viable product with a high degree of marketability and manufacturability. Initial target markets identified include owners of holiday houses, agricultural establishments, and water conscious consumers. EverGreen's reliability and remote management options make it ideal for the 3.2% of Australian household owners who own holiday houses [4], approximately one-quarter of a million dwellings. EverGreen's ability to calculate and administer the optimum amount of water based on past and future rainfall and soil type make it ideal for the 133,000 irrigating agricultural establishments throughout Australia [5]. Finally, the water saving benefits of EverGreen make it highly desirable to the 24.1% of Australians identified as being particularly conscious in saving water [6]. EverGreen uses components sourced easily from a variety of suppliers, granting a high degree of manufacturability.

2.4 Design Methodology

In developing EverGreen the Extreme Programming (XP) design methodology was used as it suited the tight deadlines of the solution and the working style of each team member. While not all of the principles were appropriate, many were utilised including small releases and simple design in conjunction with refactoring [7]. This allowed our team to consistently have stable working versions which could be incrementally built upon while enabling demonstration and feedback from our customer/business representative. In the process of refactoring quick design sessions were frequently held with planning game being used to steer the direction of the solution. Great benefit was also found in the use of paired programming with many advances being made which would not otherwise have happened if programmers had worked alone. Design and analysis tools used included UML Class Specification, state charts, and user scenarios.

2.5 Team Organisation

The team worked closely together on all parts of the solution, often pairing up to focus on specific components then re-pairing upon completion to focus on other areas. Code was collectively owned enabling changes to be made efficiently on all areas of the system. In conjunction with the use of paired programming, specific members of the team were delegated responsibility over specific components. These tasks were delegated based on the team member's strengths, to maximise their impact on the quality of the solution. We had no specialists in the team but made use of each member's specialised skills. Quick design meetings were generally held several times a week to discuss solution outcomes, steer future direction, and to ensure team organisation. The team frequently worked in close conjunction with each other and at other times relied on email and instant messaging to relay information.

3.0 Implementation & Engineering Considerations

3.1 Design Objectives

The design of the EverGreen system was guided by the following key design objectives:

Accuracy: The EverGreen system's primary purpose is to reduce the wastage of our planet's increasingly scarce fresh water supplies. To achieve this objective, it was determined that the EverGreen system **must** meet the following requirements:

- Calculate and distribute the optimum volume of water, measured to an accuracy of one litre, that is required by a garden/crop to keep the plants healthy.
- Access the latest meteorological data, both historical and predictive, for the suburb/region in which the device is operating.

Usability: EverGreen's primary market does not have high rates of computer literacy, so it is important that the device requires low levels of user interaction and that any interaction required will be as simple as possible. To achieve this objective, it was determined that the EverGreen system **must** meet the following requirements:

- Minimal user interaction, required only when first installing the system.
- Settings, status and watering history made available to the user if desired.
- All user interaction with the device is to be via a web site, which was determined to be the most familiar environment for the target users.
- Integrates easily into existing water distribution facilities.

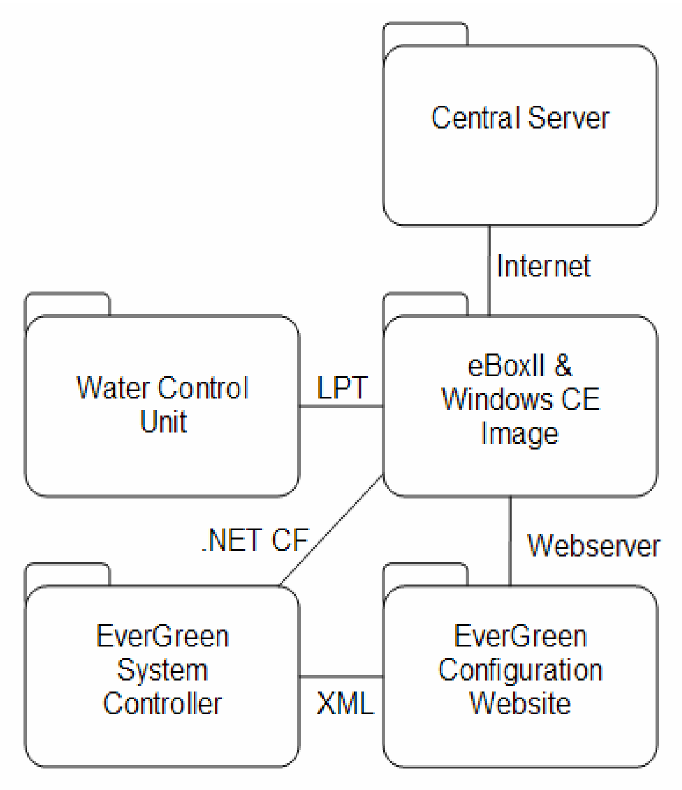
Reliability: As the device is designed to operate without user intervention it is extremely important that the system operates reliably and has the ability to handle unexpected situations. To achieve this objective, it was determined that the EverGreen system **must** meet the following requirements:

- Continuous operation in the event of an internet connection failure, compensating for errors in watering upon reconnection.
- Automatically resume operation after a power outage.
- Halt all watering in the event of a power outage or system failure.

Extensibility: The EverGreen system is designed for efficient expansion. To ensure maximum portability and versatility it is imperative that the device's configuration settings be remotely obtained. This will enable the EverGreen system to grow into new markets easily.

3.2 System Description

The EverGreen system comprises of six distinct components, two are hardware components (eBoxII and Water Control Unit) and the other four are software components (Windows CE Image, EverGreen System Controller, EverGreen Configuration Website, and Central Server).



The eBoxII is the central hardware component of the system. Within the eBoxII runs a Windows CE Image which is the operating system for the eBoxII. On top of this Image runs the EverGreen System Controller which determines when to water and how much water to deliver. Alongside the EverGreen System Controller runs the EverGreen Configuration Website that allows users to remotely configure their device's settings. The EverGreen System Controller is connected through the eBoxII to the Water Control Unit via the parallel port. The Water Control Unit is responsible for monitoring and controlling the water flow. The final component is the Central Server which operates remotely and is used to store all climate and system setting information for all EverGreen devices. The EverGreen System Controller is connected to the Central Server via the eBoxII's RJ-45 Ethernet port which allows for the required connection to the internet.

3.2.1 eBoxII

The eBoxII is a Windows CE development kit based on the x86 chipset, and produced by ICOP Technology. The eBoxII has an extensive capability list of which the EverGreen system utilises the following:

- Parallel port (LPT) support. Used as the communication medium between the EverGreen System Controller and the Water Control Unit. The parallel port was chosen over the other available connection mediums, serial port (RS-232) and universal serial bus (USB), as the parallel port easily enables the EverGreen System Controller to control multiple watering zones simultaneously.

- Permanent storage. The eBoxII has 32MB of flash memory, in which the Windows CE Image, EverGreen System Controller and configuration files reside. Flash memory was chosen over other permanent storage mediums, like hard disk drives, because the storage requirements for the system are very low and it is more cost effective to use flash memory than an external hard disk drive.

- Network connectivity. The eBoxII has a single RJ-45 Ethernet port which is used as the communication medium between the EverGreen System Controller and the Central Server. In the prototype, this connection operates through Cat 5e cable, but in production a wireless connection(802.11b/g) could be utilised by simply adding a wireless bridge to the eBoxII

- Temporary storage. The eBoxII has 128MB of Random Access Memory (RAM), which is excessive for the needs of this system. In production this could be reduced.

As each EverGreen device is a headless device the eBoxII's VGA, PS/2, and audio ports are not required, neither is the single serial port or three USB ports. The eBoxII is connected directly to mains power (240V AC 50Hz) through a 5V DC power adapter.

3.2.2 Water Control Unit

The Water Control Unit is comprised of four separate components

- Water Meter. The water meter used in the prototype is an industrial strength analogue water meter, which has both a visual and electrical output. Using the electrical output it is accurate to the nearest litre, and can operate with water between 0°C and 90°C. The visual output was necessary in the prototype to aid debugging of the system, but in production the visual output wouldn't be necessary.

- Water Valve. The water valve used in the prototype is an industrial strength electrical valve. Along with the water meter the valve can operate with water between 0°C and 90°C, and is controlled by a single 12V DC line. For the prototype, a valve that could operate without mains water pressure was selected, this enabled us to test the system with gravity fed water instead of mains pressurised water. This feature came at a significant cost premium and in production would not be necessary. The chosen valve's default state is closed; which was a very important requirement, as it forces the system to shut down the water supply safely in the advent of a power outage.

- Power Control Unit. The power control unit is used to enable the parallel port lines (5V DC) to control the 12V DC line used by the valve. This was achieved by using a transistor to increase the voltage out of the parallel port to enable it to toggle a relay connected to the 12V DC line. In production the Power Control Unit would be upgraded so it could control a mains water valve, which would mean that it could be connected straight into the mains power.

- Filter and Piping. The last component is the filter and piping used to connect the Water Meter and the Water Valve together to the mains water supply. The filter increases the lifespan of the water meter and water valve, this is especially important when connected to untreated water supplies, like those found on irrigation farms.

3.2.3 Windows CE Image

The Windows CE 5 Operating System (OS) supplied with the EverGreen device was created as a custom device, not based on a predefined macro. The image built is less than 7 megabytes including the EverGreen System Controller software. The following key functionality was included into the image:

- Web Server (HTTP) – This and other associated components were included to allow the user to configure the device through ASP (Active Server Pages) web pages with embedded Jscript code. It enables the user to enter the device's settings required for watering calculations. Using a web server provides this functionality in an easy, well known and intuitive manner.

- XML Support – After weather information has been retrieved, relevant information is extracted and stored on the device in XML format. These XML files are then used for further data manipulations in order to complete the watering process. XML was used due to its wide industry acceptance and ease of use.

- Parallel Port Driver – The parallel port is used to operate the Water Control Unit. This allows for simultaneous operation of multiple valves.

- .NET Compact Framework (plus OS Dependencies) and SQL Server 2000 – It was decided that application development will be done using Microsoft Visual Studio .Net 2003. Although this requires the OS to contain video drivers, making it a headful device, EverGreen does not require a screen. The reason for choosing to develop the majority of the application as a managed application using Microsoft Visual Studio .NET 2003 rather than as an unmanaged application using Microsoft Embedded C++ 4.0 was mainly due to time constraints. By developing a managed application we were able to achieve or exceed all design objectives in the short time frame available.

3.2.4 EverGreen System Controller

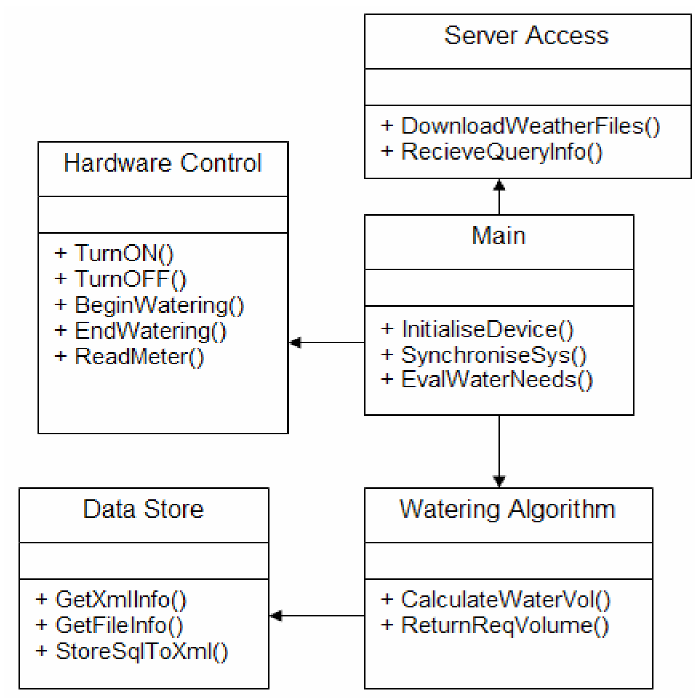
The EverGreen System Controller has two primary functions; to interface with the Water Control Unit and to synchronise with the Central Server. The EverGreen System Controller is a managed smart device application built using Microsoft Visual Studio .NET 2003. As a result of this, the Compact Framework is required.

The EverGreen System Controller comprises of five classes.

- Main Class. The main class is responisble for initialising the system and controlling the timing of watering and Central Server access .

- Server Access Class. The Server Access Class is responsible for communicating with the MS SQL database running on the Central Server. To ensure that the MS SQL database's connection pool does not empty during times of high load, all connections are kept open for the minimum possible time for each transaction. Database communication utilises the functionality of ADO.NET. Apart from database interactions, the Server Access Class is also responsible for retrieving meteorological data files. All the functions that directly access the server are encapsulated so that any requests must go through a limited public interface.

- Hardware Control Class. The Hardware Control class was developed in native code using Microsoft Embedded C++ 4.0 and is packaged as a native code dynamic linked library. The Hardware Control Class enables the EverGreen System Controller to write and read from the parallel port and thus interface with the Water Control Unit.



- Data Store Class. The Data Store Class is responsible for the reading and writing of all data stored locally on the EverGreen device. It has the ability to parse meteorological data files and configuration files.

- Watering Algorithm Class. The Watering Algorithm Class utilises the watering algorithm to determine the optimum watering volume depending on a range of factors. This class has been designed in a modular fashion, presenting a static public interface whilst maintaining a dynamic backend. The implication of this design approach is the ability to plug in different Watering Algorithm modules for different situations. For example: irrigation farmers will require a Watering Algorithm module that takes into account the increased water requirements of crops as they develop, whereas a homeowner's garden/crop will have a linear water requirement, as the plants in the garden/crop are already established. In the prototype the Watering Algorithm Class is designed to efficiently water a homeowner's garden/crop.

3.2.5 EverGreen Configuration Website

Each EverGreen device has a local website that allows the owner to interact with the device. The website allows the owner to configure their watering zones, monitor the status of the system and monitor their watering history. The website is a collection of ASP pages coded in JScript and HTML. All the data consumed and produced by the ASP pages is stored in XML format. These XML files are then used as the communication medium between the EverGreen Configuration Website and the EverGreen System Controller.

3.2.6 Central Server

The Central Server is primarily responsible for ensuring system reliability and extensibility. The Central Server is a PC running Microsoft Windows XP with Microsoft SQL Server 2000 and Microsoft IIS web server. The Central Server allows for all important data to be stored in a centralised location to enable the administrator to configure the settings used by each device remotely. To achieve this, the Central Server has the following functionality:

- Host all meteorological and restriction data for each supported location. Although this data is obtained from other sources, such as the Bureau of Meteorology, it was determined that it is more reliable for this data to be transferred to the Central Server and then accessed by each device. This will mitigate the risks of using information supplied by third party vendors. If we host the data, we can change to different data suppliers and be assured of the location of the data.

- Host the settings database. The settings that the EverGreen System Controller uses to calculate the water needed by certain plant species on certain soil types are all stored on the settings database. This enables the developers to make changes to how all the devices in the field operate by changing the settings in a single centralised place. Each EverGreen device synchronises it's settings on a daily basis.

- Host a web server and an Administrator Website. The Administrator Website allows the administrator to remotely configure the settings. It also allows an administrator or water supplier to monitor water usage patterns in each location.

3.3 Watering Algorithm

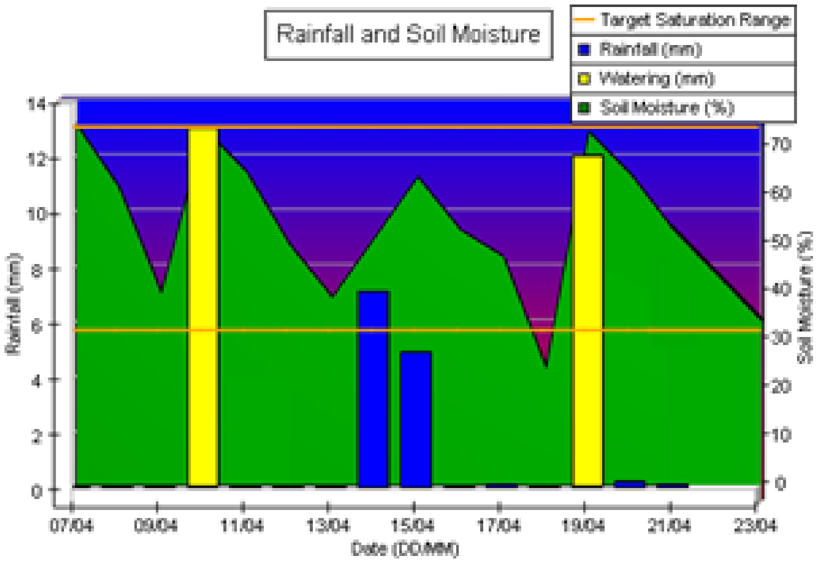
The calculations class is responsible for keeping the moisture level of the soil above the plant's wilting point, the point that the plant can no longer easily access the water it needs, and below the soil's saturation point, the point that the soil can no longer absorb water. This area is the soil's Target Saturation Range (Figure 1.0).

To achieve this, an automatic control system was implemented. The steps of the automatic control system are as follows:

1. Calculate Input: The current water level is calculated by adding the change in soil moisture (Figure 2.0) with the previous day's soil moisture level, for every record in the meteorological data file.
2. Calculate Feedback: Irrigation, the distribution of water to a garden/crop, is only supplied when the moisture level of the soil is approaching the plant's wilting point. When the irrigation is supplied it is delivered in a volume that will return the soil to 75% of its saturation point. This ensures that irrigation will only occur in sizeable quantities to reduce the water lost through evaporation.

3. Dampen Feedback: Any predicted rain is then used to reduce the irrigation volume. If predictive rainfall is not accurate adjustments are made in the next watering cycle during the calculate input phase.

Figure 1.0



The soil moisture level, as represented by the green area, decreases from its initial level of 75% to 40% due to plant water use and evaporation. Because the soil moisture level is approaching the plant's wilting point, as represented by the lower orange line, it is determined by the system that irrigation, as represented by a yellow bar, is required. 13mm is then supplied on the 10/04 to return the soil moisture level to 75%. Between the 11/04 and the 18/04 the soil moisture level is kept at an acceptable level by rain, as represented by the blue bars.

Figure 2.0

$dSW = P + I - T$	$T = ((W \times VPD) \div TE) \div 1000$
Legend dSW is change is soil water (mm) P is precipitation (mm) I is irrigation (mm) T is transpiration, water used by plants (mm)	**Legend** T is transpiration (mm) W is potential biomass increase (gm^{-2}) VPD is vapour pressure deficit (kPa) TE is transpiration efficiency coefficient 1000 is the mass-volume conversion factor of water

3.4 System Limitations

One of the main limitations of the system is that it relies on an active Internet connection to synchronise settings and obtain data. If the connection is lost, the system will not fail. Instead EverGreen will use the most recent weather predictions stored on the device to calculate watering. This should yield accurate results for some time after a connection failure. For extra safety, a user can remotely access the status of the watering system in order to determine whether a failure has occurred.

Another limitation is the accuracy of the watering model. Although the calculations performed are accurate for average situations, there are certain factors that the model does not incorporate into its calculations, for example “run-on” and ”run-off” (water displacement that occurs on slanted properties) was not considered. This was a strategic decision to ensure that useability of the product is maximised.

Variation of transpiration/water consumption in different plant species (especially agricultural species) is also not fully accounted for. Even though the user can specify low, medium and high water consumption options in the set up process, other plant species may have very specific (life-cycle based) water consumption patterns (eg. fruit trees require more water when bearing fruit). The modular design of the system allows for specific watering regimes to be implemented when plant lifecycle considerations are critical. This increases extensibility and marketability of the product.

Other limitations include English-only language support and availability of meteorological data obtained from national weather authorities. These limitations are negligible and can be addressed in the future.

3.5 System Scenarios

3.5.1 Scenario 1: Normal operating conditions

Assume a holiday house owner has correctly set up the system and the Internet connection is active. This is an ideal situation. The watering system performs the following process once each day for each configured zone.

1. Synchronise with Central Server at specified synchronisation time.
2. Store latest information into local xml files.
3. At specified watering time, taking into account watering restriction hours, check the database for previous day’s actual climate data and that day’s predicted rainfall at the user’s specified location.
4. Calculate optimum volume of water to distribute taking into account accuracy of previous forecasts to make adjustments if necessary.
5. Distribute water through watering system while monitoring flow.
6. Cease flow of water when calculated volume has been distributed.
7. Log watering volume and date.

3.5.2 Scenario 2: Internet Connection/Central Server Failure

Assume a farmer has correctly set up the system, however, due to an Internet service provider fault, the connection is inactive. The watering system performs the following process once each day for each configured zone.

1. System attempts to synchronise with Central Server at specified synchronisation time.
2. Upon failure to connect system restores data stored locally and assumes past data as predictive of future.
3. System continues operation from step 4 of scenario 1: normal operating conditions. Accuracy is diminished until Internet connectivity is restored. Users are able to remotely check if their device has lost Internet connectivity by attempting to access the configuration pages stored on the device.

3.5.3 Scenario 3: Blackout

Assume a user has correctly set up the system, however, due to a power outage, the device has been turned off.

1. When power goes out, valve immediately shuts off and watering is halted, if watering.
2. On reconnection of power the device reboots.
3. EverGreen System Controller automatically starts up and begins controlling the device.
4. The EverGreen System Controller checks stored files to determine location and set up information. Synchronisation may occur if necessary.
5. Device continues operation from step 3 of scenario 1: normal operating conditions.

3.5.4 Scenario 4: User wishes to halt or modify operation of system

This scenario could occur in an agricultural situation where crops are being harvested, cleared or sown and watering is either not appropriate or watering conditions have changed. In a home situation, this could be when a garden/crop is being landscaped or replanted, or when major renovations are being undertaken.

1. User remotely accesses menu system provided by EverGreen through configuration web pages stored on the device.
2. User selects to disable the system or change watering parameters. The device can also be restarted through this process.

3.6 Testing Plans & Results

Reliability and accuracy were two of the primary performance drivers behind the development of EverGreen. To ensure high levels of these factors, EverGreen was rigorously tested throughout the development process. Following the principles of small releases from the Extreme Programming design methodology, the various EverGreen system components were integrated early on in the process which allowed for testing of the whole system from an early stage. During development programming pairs would focus on testing the components they were developing in conjunction with other components where available or using stubs and drivers when necessary. After each small release the team would perform integrated tests of the entire system and assess the results based on our performance drivers. Test plans were created for both unit testing and system testing. Unit tests enabled testing of specified components outside of the complete system. Testing in this isolated environment allowed faster discovery of certain bugs in components.

Test results evolved over time throughout each small release as bugs were found and repaired and as continuous improvement moulded the design into a more sophisticated system. Tests performed on the final small release before submitting this report measured a watering distribution accuracy of within 1 litre from the calculated value. Tests for reliability were performed by placing the system under a variety of predefined situations to observe how it would respond. By the final iteration, EverGreen passed all these tests, though it was noted that in situations where EverGreen lost its Internet connectivity accuracy of determining appropriate water volume would drop drastically after the next rainfall. In situations where the eBoxII lost the image stored on it due to data corruption or other imposing factors, the EverGreen system could not restore.

3.7 Alternate Solutions

Some commercially available watering systems use soil moisture sensors, some use timers, some use a combination of both in conjunction with additional hardware. One of the best ways to evaluate alternate solutions is to look at products currently on the market.

Timed devices ignore all environmental conditions and deliver water based only on a user-specified regime. These devices are prone to mass water wastage and if improperly used can represent a threat to water storage levels. These devices are commonly misused and their use is heavily restricted.

Watering systems that use soil moisture sensors aim to do a similar job to EverGreen but fall far short for the following reasons. If they were to be used over large areas such as farms, they may require many sensors in order to accurately gauge the moisture over an area of crops. This increases the risk of failure, as there are numerous hardware components. These components are at risk of damage by people, farming machinery, rodents, and weather. Defective devices could be a considerable distance from the main system and, unless properly designed, it may be impossible to determine which component is damaged, making it very time consuming to find the faulty device. Systems that implement sensors still regularly waste water as they cannot evaluate forecast predictions in watering calculations and may water heavily just prior to a major deluge. Finally, moisture sensor based devices cannot efficiently determine how much water to distribute due to a lengthy feedback loop.

An alternate solution to achieve predictability and possibly increase accuracy of the watering system would be to add a combination of temperature, moisture, humidity and rain sensors to the device, essentially making a “mini weather station” wherever the device is installed. This could arguably increase accuracy, as each device is configured for its own location. It would also remove the need for an Internet connection; however, it is also arguable that if an expert does not set up this “mini weather station”, results may be disastrous. As an example, if the user were to inadvertently set up the device under some shelter (under a tree, or next to a wall) results obtained from the system would be flawed and over watering could easily occur. As with any system that uses numerous hardware components, they are susceptible to failure and damage. The alternative, to get the same information from a reliable source, minimises set up time/cost and maximises reliability and useability, whilst making the entire system much easier to maintain.

3.8 Development Tools

The following tools were used in developing EverGreen:

Platform Builder

To develop the image for the eBoxII, Platform Builder for Microsoft Windows CE 5.0 was utilised. A “Custom Device” macro was utilised as the basis for the image with only the required functionality being added to the final image. In order to have the desired application files stored in the correct directories on start-up, Mike Hall’s CEFileWiz was used to create custom catalogue items with the necessary settings.

Various tools in Platform Builder were utilised:

- The remote file viewer was used to upload/download files for testing and debugging which was especially useful during the creation and testing of EverGreen’s web based configuration interface.

- The remote registry editor was utilised to take snapshots of the registry before and after changes. This allowed registry changes to be made in order to automatically start up core applications.

- The Smart Device Authentication Utility was added to images for testing the evergreen application that was developed in C#

- The remote process viewer and the ability to start processes through platform builder also aided in testing the platform with applications.

Microsoft Visual Studio .NET 2003

Microsoft Visual Studio.NET 2003 was used to create the EverGreen System Controller which constantly controls the operation of the eBoxII. The language used was C#. The smart device authentication utility was utilised to allow deployment and debugging of applications on the eBoxII.

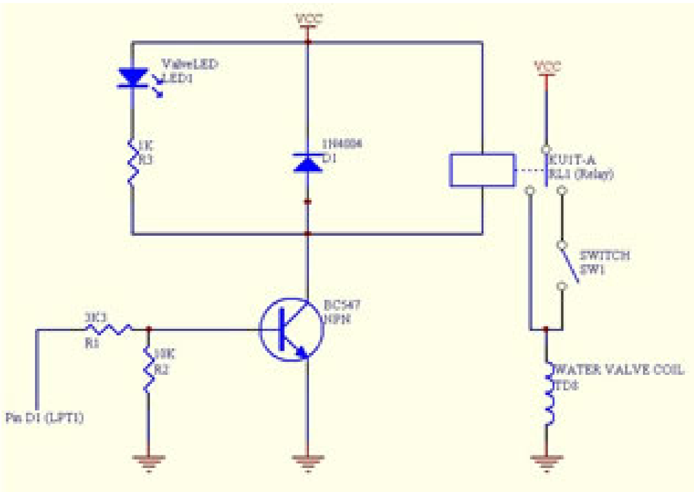
evC++

Embedded Visual C++ was used to create a dynamic linked library (DLL) that accessed the parallel port. This DLL was invoked in .NET using platform invoke.

The following tools were developed in building EverGreen:

Water Control Unit

The design for the water control unit was developed using Protel98 [8], a CAD program for developing circuit schematics and printed circuit board (PCB) diagrams. The PCB design was then constructed using the facilities provided to students by RMIT University.



Hardware Assembly

Assembly of hardware components, including the water meter, water valve, water filter, and water control unit was completed by the development team.

3.9 Costing

Below are the costs associated with developing the hardware prototype:

Item	Price ($USD)	Price ($AUD)
12V 9W Valve Coil	$17.20	$22
Y-Strainer ¾”	$8.60	$11
¾” Air/Water/Oil Direct Acting Valve	$86	$110
20mm Cold Water Meter TD8	$38.70	$49.50
20mm Nut & Tail Kit	$8.60	$11
CYBLE Pulse Kit (For Water Meter)	$55.90	$71.50
Electronic Components (approx.)	$8.60	$11
12V Power Supply (approx.)	$17.20	$22
Misc. connectors & components (approx.)	$17.20	$22
TOTAL	**$258**	**$330**

US prices are based on AU prices converted with exchange rate set to 78 US cents = 1 AU dollar. Unless stated as approximate, these costs are actual prices at the time of purchase. It is expected that the cost of a prototype is much higher than that of the commercially released product. Items bought in bulk would not attract such a high price and some taxes could also be ignored. Furthermore, the prototype had to satisfy special considerations (eg. operation under low water pressure in the case where a bucket must be used instead of a tap for demostration) which increased the cost significantly. The water meter obtained for the prototype is another area where costs could be reduced. The meter used in the prototype not only has a digital switch, but also a fully functional visual display accurate to 1/20th of a litre. This would not be necessary for the purposes of the commercial system but was useful in debugging and testing. Taking these factors into consideration, the device is substantially cheaper to produce for the commercial market.

4.0 Summary

4.1 Current Stage of Development

A fully functioning prototype has been developed and extensively tested which comprises the following functionality:

- Operates independent of user interaction after initial configuration.
- Synchronises settings with Central Server and obtains required meteorological data files through an Internet connection.
- Calculates optimum watering volume based on provided meteorological data.
- Controls the distribution of water and monitors flow to ensure the amount of water distributed is accurate to within 1 litre of calculated result.
- Provides remote configuration and monitoring options for users in a familiar and highly useable manner.
- Advanced configuration settings are available for advanced users to gain the most from the system including the ability to specify the synchronisation time with the Central Server so an Internet connection does not need to be active permanently. Advanced settings are not required for the system to operate.
- Administrators able to add additional locations, soil types and other settings through a web interface then update all devices in operation with the new settings.
- Redundancy features increasing the reliability of each device and allowing them to operate in disconnected states, when data files have been corrupted, or when a power outage causes a system reboot. EverGreen System Controller automatically starts up upon power up of device.
- Safety features to ensure a device is never blocked indefinitely while watering causing wastage of water. For example if a device loses power while watering the hardware has been designed to shut down the valve automatically to stop the flow of additional water.

4.2 Future Development

Although the EverGreen Intelligent Watering System is a fully functional and original solution to a well defined real world problem, it is acknowledged that there is room for further innovation in order to make the product more marketable. Further developments could include the addition of a GSM/Satellite communication device to allow the system to access remote information without the need for a conventional Internet connection. This would be very useful in an agricultural situation where the system may be many kilometres from the nearest dwelling.

To accommodate the agricultural industry further, the development of water calculation models for specific plant species and crops could be developed. These different models could be sold individually to farmers and tailored to their needs allowing for greater flexibility and the potential for a variety of sophisticated pricing plans. The modular design of the EverGreen System Controller would allow for these new calculation models to be integrated into the system with minimal effort.

Larger homes and farms may also require different zones to be serviced using alternate watering models. This has been anticipated and the application has been written to allow extra valves to be “plugged in” to the system

5.0 References

[1] Australian Bureau of Meteorology 2003, *Drought Statement April 2003*, viewed 12 April 2005. < http://www.bom.gov.au/announcements/media_releases/climate/drought/20030404.shtml >

[2] Perth Water Corporation 2005, *Water Storage in Our Dams,* viewed 12 April 2005. < http://www.watercorporation.com.au/dams/dams_storage.cfm >

[3] South East Water 2005, *How Water Smart Are You?*, Melbourne.

[4] Newton, P 2001, *Human Settlements*, Department of Environment and Heritage, Canberra.

[5] Australian Bureau of Statistics 2001, *Agricultural Census*, ABS, Canberra.

[6] Australian Bureau of Statistics 1995, *Housing Trends*, viewed 14 April 2005. <http://www.abs.gov.au/ausstats/abs@.nsf/94713ad445ff1425ca25682000192af2/2246f5f68eccdc4fca2569ee0015d8c1!OpenDocument >

[7] Jeffries, R. Anderson, A. Hendrickson, C 2000, *Extreme Programming Installed*, Addison-Wesley Professional, America.

[8] Protel 2005, *Protel*, April 2005. < http://www.protel.com.au >