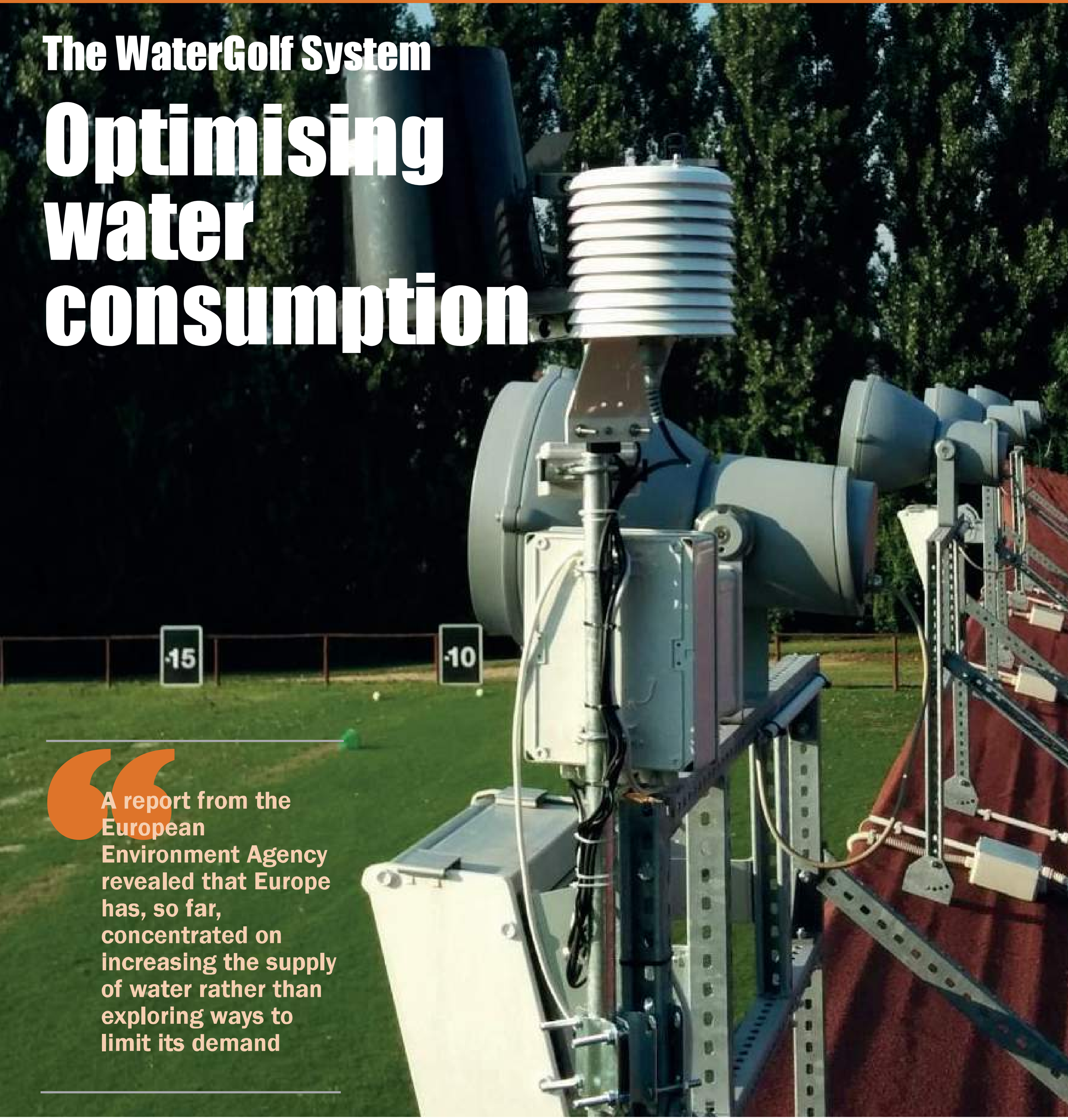
The WaterGolf System

Optimising water consumption

"A report from the European Environment Agency revealed that Europe has, so far, concentrated on increasing the supply of water rather than exploring ways to limit its demand



With water becoming such a valuable commodity, a new system, using Artificial Intellegence and part financed by the European Union, promises to reduce its consumption along with highlighting disease threats out on the course

Recreational water takes up a growing percentage of total water use and it is sourced either from mains, reservoirs or wells. These three categories of water supply all come with their own specific issues and environmental/social implications: mains water irrigation (where allowed) directly subtracts water for civil use and is subject to 'hosepipe ban' restrictions, reservoir water supply is finite and not often able to cope with the yearly water consumption of a golf course, whilst well water pumping is often seen as particularly detrimental to underground water reserves.

A report from the European Environment Agency (EEA) revealed that Europe has, so far, concentrated on increasing the supply of water rather than exploring ways to limit its demand. Golf courses are often targeted as using excessive amounts of water, especially in drier regions, where even some governments have labelled golf course usage as agricultural in order to deflect environmentalists charges of wasting water. This is why the sector urgently needs to find ways for optimising its water consumption by increasing efficiency and using innovative technologies.

Furthermore, recent EU regulation (Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009, establishing a framework for Community action to achieve the sustainable use of pesticides) is aimed at progressively limiting or eliminating altogether the use of pesticides in EU Europe. As such, in future years, the pressure will be on golf courses to limit the use of water and pesticides.

The WaterGolf system, developed with financial support by the EU within an FP7 project by the same name, deals with the optimisation of water consumption of golf courses, but also with the enhancement of their maintenance and management, by providing an intelligent system to prevent and manage turfgrass diseases, the growth of weeds and fertility problems.

Artificial intelligence has been applied in the past to precision farming to achieve optimisation in the use of water and fertilisers, amongst others. However, in the case of turfgrass, little previous work on management through artificial intelligence can be found and no current technology is available to predict the onset of turfgrass problems (weeds and/or fungi). Several systems, such as Toro, Bailoy, UgMO, ETS-Controls or Rain Bird allow computerised control of golf courses, but they do not use intelligence systems.

The objective of the project was to develop a system based on a wireless sensor network and an embedded Artificial Intelligence (AI) system that provides support to the irrigation processes on golf courses. Based on the estimations provided by the expert partners of the project, the expected impact is to save approximately one third of current annual water usage.

The system integrates underground sensors, capable of measuring soil humidity, salinity and temperature; traditional atmosphere sensors and evaposensors, capable of monitoring turfgrass evapotranspiration, in order to gauge daily water consumption by plants. The measurements are then wirelessly transmitted through nodes to the coordinating device, where the AI driven software supplies suggestions for irrigation in different regions of the course, as well as informing of potentially looming turfgrass diseases and weeds.

System Overview

The general layout of the system (Figure 1) is composed of a central server and the client software. The central server is deployed as an API which is accessible through a web-service interface, allowing other systems to monitor a golf course. Further integration, such as direct cooperation with a third-party irrigation system, is also envisaged.

The software supplies suggestions for irrigation in different regions of the course, as well as informing of potentially looming turfgrass diseases and weeds

The client software is divided into the following subsystems:

- the main dashboard, which can be used as a desktop application to manage the entire system
- the server, which is in charge of the management and processing of all data fetched from the golf course and to deal with external requests
- the mobile-device application, in charge of managing remote notifications
- the consultancy system, which is a tool for the expert consultant to remotely advise the greenkeeper

Note that a complex network of advanced sensors is also used in the system. The sensors used are underground sensors, which gather measurements of soil temperature, salinity, humidity; evapotranspiration sensors, which determine the evapotranspiration measurements of the turfgrass; weather stations, which measure air temperature, precipitation, wind direction and wind speed. All devices communicate with one another through a wireless network, and then the gateway gathers all the required measurements. Later on, the back-end retrieves this data from the gateway.

User interfaces

The system provides the following user interfaces (front-end), mainly for golf greenkeeper use, but access can also be granted to the course's turfgrass consultant:

Desktop application

This is the default client software that is used by the greenkeeper on a standard stand-alone deployment. It allows the management of the entire system through web-method calls to the server API. Suggestions and irrigation recommendations are shown in the main screen, while all complex behaviours are only revealed to an advanced and password-protected user. It is developed using a 2-tier architecture: the user interface layer (for user interactions) and the middleware layer (for communications with the back-end). It is also possible to use it away from the golf course (at home, while commuting, etc.).

Mobile application.

It is based on the desktop application, but does not fully replicate all functionalities as it is a simplified version with read-only access to current notifications and data.

Consultancy application

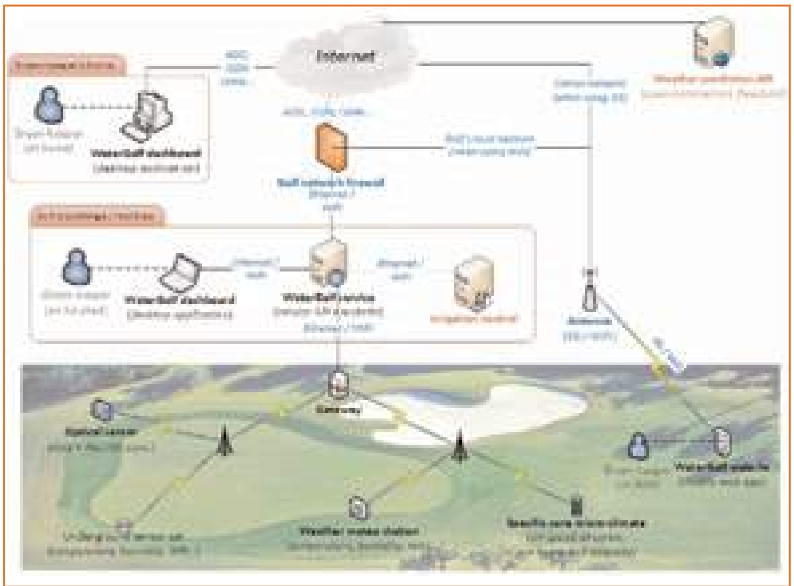
The system provides adequate recommendations, but there is the possibility that complex and dangerous situations appear, which require the participation of a turfgrass expert. In this case, the greenkeeper can consult a turfgrass expert. This subsystem provides the turfgrass expert with the appropriate interfaces to access relevant data, communicate directly with the greenkeeper, and maintain the system remotely by using an expert system rule editor. An advanced indexing service is also provided for accessing to documental data. The service consists of a repository of relevant documents (informative, technical data sheets, specialised, technical, scientific papers, etc.) where the consultant must be able to manage documents.

Back-end application

This is the kernel of the system and is implemented as a dynamic link library (DLL). The library exports the classes and methods as web-services. The web-services interface has been developed using Windows Communication Foundation (WCF). It can be exported using the RESTful, SOAP or Net.TCP technologies.

Intelligent System

Figure 2 shows a general layout of the intelligent system, which is hosted in the API and retrieves sensor-derived information and



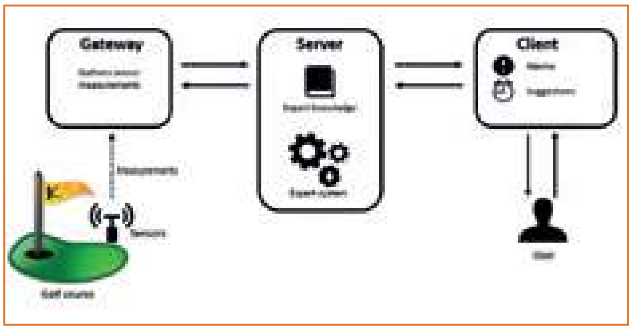


Figure 1 (left): The general layout of the system is composed of a central server and the client software. The central server is deployed as an API which is accessible through a web-service interface, allowing other systems to monitor a golf course

Figure 2 (above) shows a general layout of the intelligent system, which is hosted in the API and retrieves sensor-derived information and stores it in a database

The control of fungi plays a large role in golf course turfgrass management, both in financial terms and from an environmental viability point of view

WaterGolf node device

stores it in a database. The expert knowledge is embedded in the API and uses the sensor measures, turfgrass knowledge compiled by turfgrass experts, plus other vital parameters to be provided by the greenkeeper at the first system installation (turfgrass species and soil/substrate type). The intelligent system is then divided into three different experts systems, one for each type of treatment (irrigation, weeds and fungi).

Irrigation Expert System

The irrigation expert system is based on a water 'reservoir - consumption - gauge' architecture. Water 'reservoir' is dictated by soil/substrate type, typical species root depth according also to the golf course area being monitored (i.e. bentgrass roots on greens or fairways differ in depth). Water "consumption" is supplied in millimetres by the evaposensors, with data corrected according the specific Kc of the different turfgrass types, and the water "gauge" is simply represented by the soil water content sensor(s).

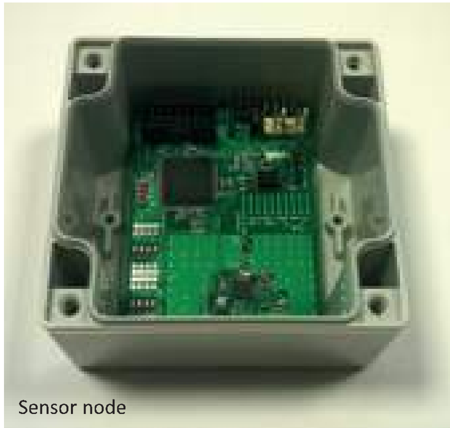
The irrigation expert system gathers measurements from the evapotranspiration and the underground sensors to obtain the evapotranspiration value and the soil water content respectively. The system also requires the greenkeeper to introduce the following parameters: first, it needs to know the soil type where the sensors are placed. Different soil types (and substrates for greens) have different Available Water Content (AWC, where AWC = field capacity - wilting point). Second, the turfgrass type also needs to be specified since it carries information on its specific Kc for evapotranspiration evaluation and on the typical root depth of the species. Taking these values into account, the system is able to estimate the time before complete water depletion in the corresponding golf course zone, and the necessary amount of water that must be reintegrated to the soil, and a Windows Workflow Foundation (WWF) rule engine manages the alarms and suggestions related to irrigation.

Please note that the greenkeeper can work within his set 'confidence level', which is a predetermined percentage of soil water content depletion. That is, the system can inform the greenkeeper on 'hours before the predetermined water depletion is reached'. This confidence level can be progressively increased, for maximum water use optimisation, as the greenkeeper gains trust in the system.

Turfgrass fungal disease Expert System

The control of fungi plays a large role in golf course turfgrass management, both in financial terms and from an environmental viability point of view. The following common fungal diseases were selected and researched for etiology parameters: Pythium blight *(Pythium spp.)*, Yellow patch *(Rhizoctonia cerealis)*, Dollar spot *(Sclerotinia hoemeocarpa)*, Anthracnose *(Bipolaris spp.)*, Anthracnose *(Drechslera spp.)*, Pink snow mould *(Michrodochium nivale)* and Red thread *(Laetisaria fuciformis)*.

A large number of numeric parameters are available in bibliography, and these were all included in the rules for fungal disease, since the turfgrass type needs to be determined (different susceptibility to various turfgrass diseases can be attributed to the various turfgrass types). Also, soil and air temperature and air relative humidity are used as input parameters, measured by the soil sensors and by a weather station. The system outputs for fungal disease forecast and management comprise both a disease and turfgrass specific probability calculation equations, and the issue of a compendium of available chemical products for fungal disease treatment and prevention, including their dosage.



Sensor node

Weather stations measure precipitation, wind direction and speed

Taking this into account, the system determines the probability of the previously specified fungal diseases based on the previously mentioned parameters (considering that each fungal disease depends on different parameter combinations and ranges). Three alarm levels have been defined to indicate the probability of onset of each fungal disease: no alarm (P<0.5), low probability alarm (0.5<P<0.7), and high probability alarm (P>0.7). In this last case, the system could also recommend the active principle and dosage to fight the fungal disease, but this option is on hold due to the difficulty of keeping up with local national regulations on active principles allowed for use on non-agricultural areas.

Golf course weeds Expert System

The control of turfgrass fungal diseases has a similar financial and environmental impact on golf courses as weed management. Not enough numerical data on the etiology of common golf course weeds is available, despite the large amount of research that has been carried out by turfgrass universities. Therefore, after having selected seven of the most common golf course weeds (crabgrass, foxtail, goosegrass, white clover, daisy, dandelion, annual meadowgrass/bluegrass), the turfgrass expert partners found that only two types of numerical etiology data were available: Growing Degree Days (or GDD; a measurement of the growth and development of plants and insects during the growing season) and soil/air temperatures, being the GDD dependent on the other.

Thus, GDD is the method employed in the system to determine the eagerness of the most


User interfaces are primarily for the head greenkeeper ...


... but may also be accessed by the course's turfgrass consultant

common green course weeds of appearing based on the average soil and air temperatures. Since GDD requires the meteorological readings within a time window (usually all readings previous to the weed germination), the platform retrieves and stores the measurements of the meteorological station that goes with the WaterGolf infrastructure. Then, according to the accumulated difference between the average air/soil temperature and the weed basal temperature (unique to each weed type) and only when the average temperature is above the weed basal temperature, different thresholds to determine the probability of each weed appearing are defined.

More specifically, three alarm levels have been defined: no alarm (the probability of a certain weed is close to 0%); low probability alarm (there are certain evidences indicating that a weed may grow, but the system cannot ensure it, which launches a warning); and high probability alarms (there is firm evidence of weed germination, so we prompt the greenkeeper with an alarm to take action).

As a final note, take into account that WaterGolf does not indicate what chemical products to use for the weed eradication to avoid any potential misuse or error. These thresholds can be modified by the greenkeeper, using a rule engine editor similar to the one used for irrigation.

Conclusions and Future Work

The WaterGolf system is trying to approach golf course management from a very advanced precision turfgrass management point of view, and no other currently available system makes such extensive use of sensors and Artificial Intelligence.

The system's first prototype was installed in the summer of 2014 at Montecchia Golf Club in Padua, Italy and validation of the system is currently underway under supervision by turfgrass experts at the Italian Golf Federation.

The first results on the overseeded Patriot hybrid bermudagrass fairways and on the bermudagrass and bentgrass greens are very encouraging, with the system being able to predict the onset of dollar spot and reacting well by supplying accurate data on irrigation throughout a very wet summer.

Acknowledgments

The work described in this article was carried out as part of the WaterGolf project, and has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement number 315054.

Article authors: Gerard Pons - EDMA Innova, Vulpellac, Girona, Spain, Alessandro De Luca - Italian Golf Federation, Sutri, Italy and Claudia De Bertoldi - Turf Europe Srl, Pisa, Italy.

Careers at Maxwell Amenity Ltd

Maxwell Amenity Ltd

Maxwell Amenity is a fast growing, dynamic sports turf company. With major brands including Pitchcare.com and Amenity Land Solutions (ALS), we are always looking for motivated and talented individuals to join our team. If you are looking for a genuine opportunity to turn your skills, knowledge, ambition and drive into a brilliant career with an exciting, professional and friendly company, we would be delighted to hear from you.

Whatever your field of experience or qualifications – if you have initiative, enjoy working with people and possess a positive attitude, we would be keen to see your C.V:
email careers@maxwellamenity.co.uk
or see current vacancies at
www.maxwellamenity.co.uk.

"I joined Maxwell Amenity just over three years ago after previous experience as a 1st Assistant Greenkeeper. The *support and expertise* of our modern, ambitious and forward thinking team has allowed me to *grow my knowledge*, profile and customer base extensively within a relatively short period of time. I call on a *diverse range of sports clubs* and customers, from Premier League Football Clubs and County Cricket grounds through to schools and bowling greens. I *genuinely enjoy* the variety the role provides and the people I meet, socialise and do business with on a daily basis."

Mark Allen
ALS Regional Manager - Technical Sales

W: www.maxwellamenity.co.uk T: 01952 897910 Allscott Park, Allscott, Telford, TF6 5DY