Development of an Object-oriented Framework for Environmental Information Management Systems in Horticulture

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Abstract

The environmental aspects of agricultural and horticultural production systems have received increasing interest in the recent years. As such there is increasing demand by customers, food industry and governmental authorities for information on the different environmental impacts of the underlying production systems.

Software tools using state of the art computer technologies could assist in providing this information by automated on-site data collection and processing. A profile as well as a conceptual framework model for the implementation of such a tool for an environmental information management in horticulture is presented.

INTRODUCTION

In recent years environmental aspects of agricultural production systems have received increasing interest among the public. As a consequence there is growing demand for information regarding the environmental performance of companies operating in the agri-sector and the environmental properties related to agronomic and horticultural products. Therefore aspects of process quality becomes more important than the physical characteristics of a product as a factor influencing customer purchase decisions. Other than physical characteristics, like visual, odorous or haptic attributes, process quality is not inherent to the product itself and has to be made available as additional information to the customer. The provision of this information results in an additional expenditure for the grower, but provides the opportunity to increase market value. Apart from the satisfaction of customer demands there are also some further internal and external benefits of comprehensive information management for agricultural producers such as the prevention of trade barriers, reduced legal liability and the possibility of improving operational efficiency and optimising consumption of resources.

A generalized approach of an environmental information management for horticultural production systems has to deal with two main objectives:

- Other than in industrial production, environmental impacts relevant in agricultural production are strongly influenced by site-specific factors; e.g. the amount of nitrate loss depends on the properties of the soil, climatic conditions (evapotranspiration, precipitation) and the crop grown on a field. As it is not workable for a practical approach to measure such an impact directly, appropriate models that take those site-specific factors into account have to be used. Of course the collection and processing of these site-specific input data increases the expenditure required to maintain a comprehensive information management system.
- the second objective is a simple economical requisite: the costs related to the usage and maintenance of an information management system should not exceed its attainable financial benefits. This economical demand conflicts with the first objective of a comprehensive and site-specific data collection.

Advances in information technology and automation in recent years lead to the opportunity to realize environmental information management solutions for agriculture and horticulture. Within the project 'Environmental Management in Horticulture' of the

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Technische Universität München a conceptual framework for an information management system for horticulture was designed and implemented considering both competing objectives mentioned above.

DESIGN OBJECTIVES OF AN ON-SITE INFORMATION MANAGEMENT SYSTEM FOR HORTICULTURE

Besides growers the target user groups of the implementation are horticultural advisors as well as scientists. The primary design objectives for the framework result from the demands of the potential users as well as the demands of the parties requesting information, like customers, governmental authorities and the food industry. These objectives are

- flexibility: As the focus of interest on information regarding the environmental performance of a system varies with the audience (e.g. customer, grower, public authorities), the tool should be capable of providing the requested information in a relevant form. For example, a customer might be interested in an environmental impact related to a unit of the product he purchases (mg nitrate leakage per kg product), while governmental authorities might be interested in an impact indicator that relates to an area unit as a proof of environmental compliance (mg pesticide leakage per square meter)
- independency: The system architecture should avoid proprietary hardware and software environments to reach a broad clientele. Usage of standardized interfaces and data exchange formats enables communication with external resources (ISO 1999, SPOLD 1999)
- transparency: One of the main objectives of this information management approach is an increased transparency of horticultural production systems by providing process information. Additionally the methods and techniques used in acquiring these information must be reproducible. This applies especially to the models used for estimating environmental impacts
- scale: The system architecture must be modular and scalable. To ensure that the best scientific knowledge is used as basis for impact assessment the system must readily accommodate modular replacements and enhancements. This objective applies to the models used in the framework as well as to the underlying database which provides data on specific system components (e.g. evapotranspiration coefficients for specific plant species).

CONCEPTUAL FRAMEWORK OF THE SYSTEM

A fundamental task in developing a tool for information management concerns the representation and management of real-world information to abstract entities that can be handled by the computer. For this modelling purpose an object-oriented design approach was selected. In object-oriented programming, so called “objects” are used as representations of real-life entities. Objects - as do their corresponding real-life entities - share two characteristics: each object has a state and a behaviour. An example for such an object is a tractor: it has state (like weight, maximum speed, power etc.) and behaviour (go forward, go backward, brake etc.). The representation of a real-world system in this modelling approach can be viewed as a population of interacting objects, each of which is an atomic bundle of data and functionality (Yourdoncs, 1979).

The aim of the conceptual framework of the information management system is the analysis of single horticultural companies. Therefore the main object type used in the model represents one company. Each single company object consists of an arbitrary combination of sub-objects. These sub-objects are classified per the following object types:

- Area objects: represent the fields that are available for crop cultivation within the company.
- Crop objects: represent a plant species cultivated on a specific area object at a specific date.

- Device objects: basically represent machine objects like tractors, tillage machinery, irrigation equipment etc.
- Process objects: an abstract object type defining the usage of one or more device objects on a crop or area object (e.g. a "ploughing process" could consist of a tractor object and a plough object which are used on a specific date for tillage of a specific area object).

Each of these basic objects may interact with other objects, e.g. each crop object is associated with exactly one area object, a process object is associated with zero to many device objects etc. The mandatory and/or possible associations between objects are shown in the Entity-Relationship model in figure 1.

By choosing specific components from a database of predefined object templates, customization of those objects and definition of associations between single objects, it is possible to represent an individual horticultural company. Figure 2 shows a hardcopy of the user interface of the information management software. On the left the object structure of the sample company is shown as an object tree, with each of the main tree branches holding objects of the same type (area, crop, device and process). For better usability and clarity each branch is further divided into dynamical sub-branches like process type (e.g. irrigation) and the season an object is associated with (process, crop). Note that this tree representation is a simplification of the real object structure, because object associations may exist between the different branches (e.g. all of the crop objects from the crop branch are associated with area objects in the acreage branch). In fact the real object structure rather approximates a complex network of the single objects than the strongly hierarchical tree structure. Even so, the tree structure was selected for the user interface because of simplicity, usability and clarity.

The custom and site-specific object structure that represents an individual horticultural company can now be used to assess the environmental impacts related to the production system. For the assessment of the impacts, current scientific models and methods will be used. The input data required, by these models, are provided by the objects of the object model: the objects state, the objects behaviour and the objects associations. Figure 2 shows the calculated evapotranspiration that occurs on a specific area object (although evapotranspiration itself is not an environmental impact it strongly affects impacts like water loss, potential soil compaction and nitrate loss). The data used for the evapotranspiration calculation were provided by the following objects:

- Climate data: the climate data object is similar to a table holding daily datasets for temperature, humidity, wind speed, radiation, precipitation etc. In the current implementation weather can be imported via internet (from publicly available climate databases) or from a local source.
- Area object: provides the soil type and actual soil moisture. Both object states have influence on evaporation from the topmost soil layer. Different soil types and the appropriate soil properties are supplied as standard components by the underlying database. Soil moisture is calculated using those soil properties and climate data. Figure 3 shows a dialog that enables the customization of single area objects.
- Crop object: provides the transpiration coefficient that depends on plant species, development state of the plant and the percentage of ground covered by plants. As soil types, different crop species and their transpiration characteristics are supplied by the underlying database as predefined components.
- Process object: processes of types of irrigation affect the soil moisture, which again has influence on evaporation of the topmost soil layer.

For the calculation of the evapotranspiration data shown in figure 2 the Penman-Monteith model as proposed by the FAO (Allen, et al., 1998) was used. Because of 'pluggable model' architecture, the usage of specific models is not fixed. Alternatively any custom model that implements a common model interface could be integrated and used in the application. In figure 3 daily water balance related to a specific area object is shown. Water balance is the sum of precipitation, irrigation and evapotranspiration. The daily water balance is used for the calculation of soil moisture.

CONCLUSIONS

The presented framework model outlines the basic concepts for the implementation of environmental information management software for practical usage in horticulture. It is obvious that the quality of information derived from the environmental management software strongly depends on the quality of the input data supplied to the underlying impact models and the quality of the models itself. So ongoing development in the fields of automated data acquisition and scientific modelling may contribute to the steady improvement of environmental management systems. To enable the future integration of current scientific knowledge the definition and usage of standardized interfaces and data formats will be necessary; e.g. the “pluggable model” architecture used for the implementation presented in the paper enables the modular replacement and enhancement of models used by the system.

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Figures

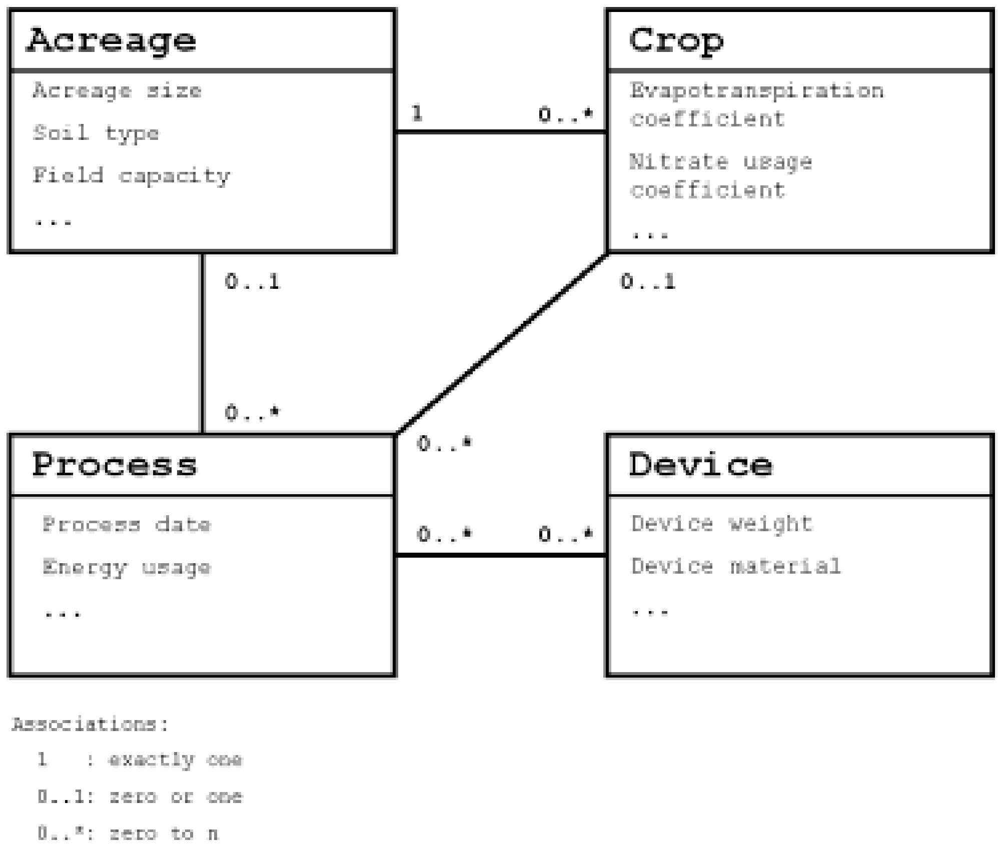

Fig. 1. E/R (Entity/Relationship) model of the main object types of the framework and parameters provided by these objects.

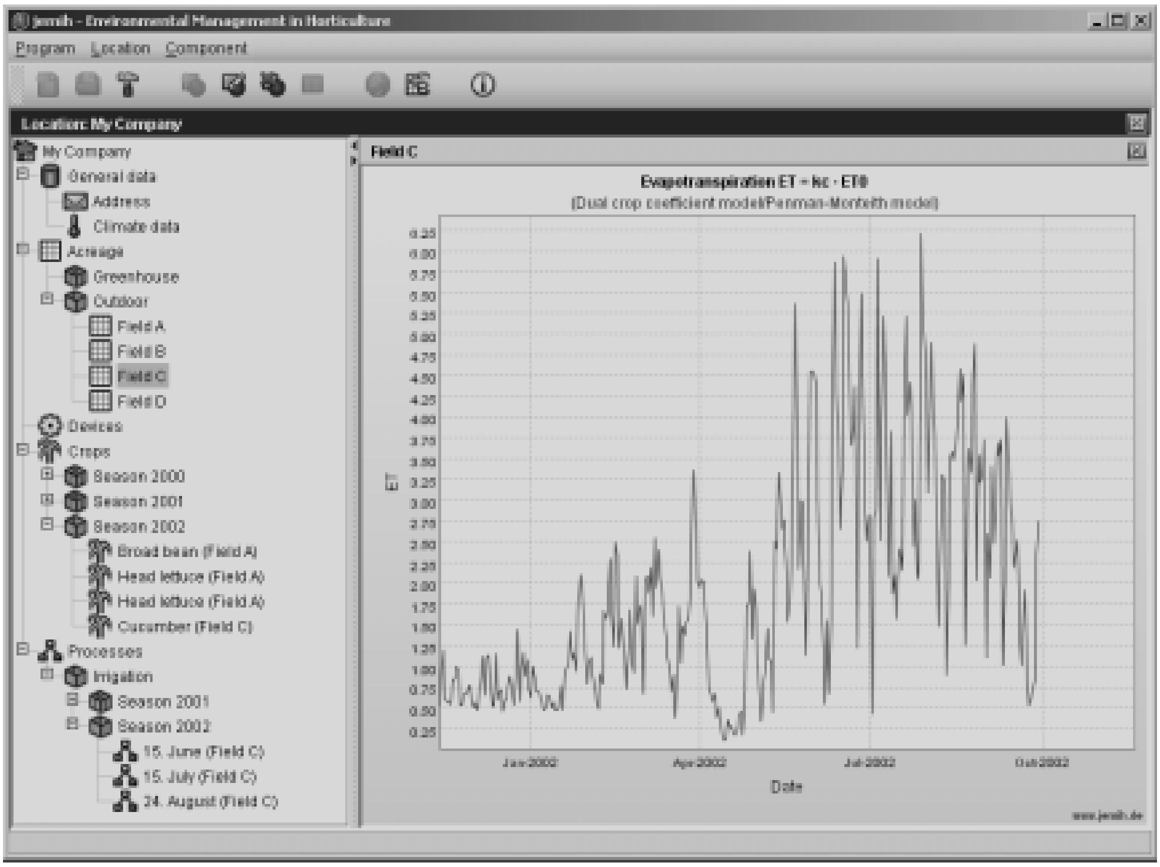

Fig. 2. The user interface of the information management software, showing a tree representation of the objects of the horticultural production system 'My Company' on the left and the modelled evapotranspiration occurring on field object 'Field C' in 2002 on the right.

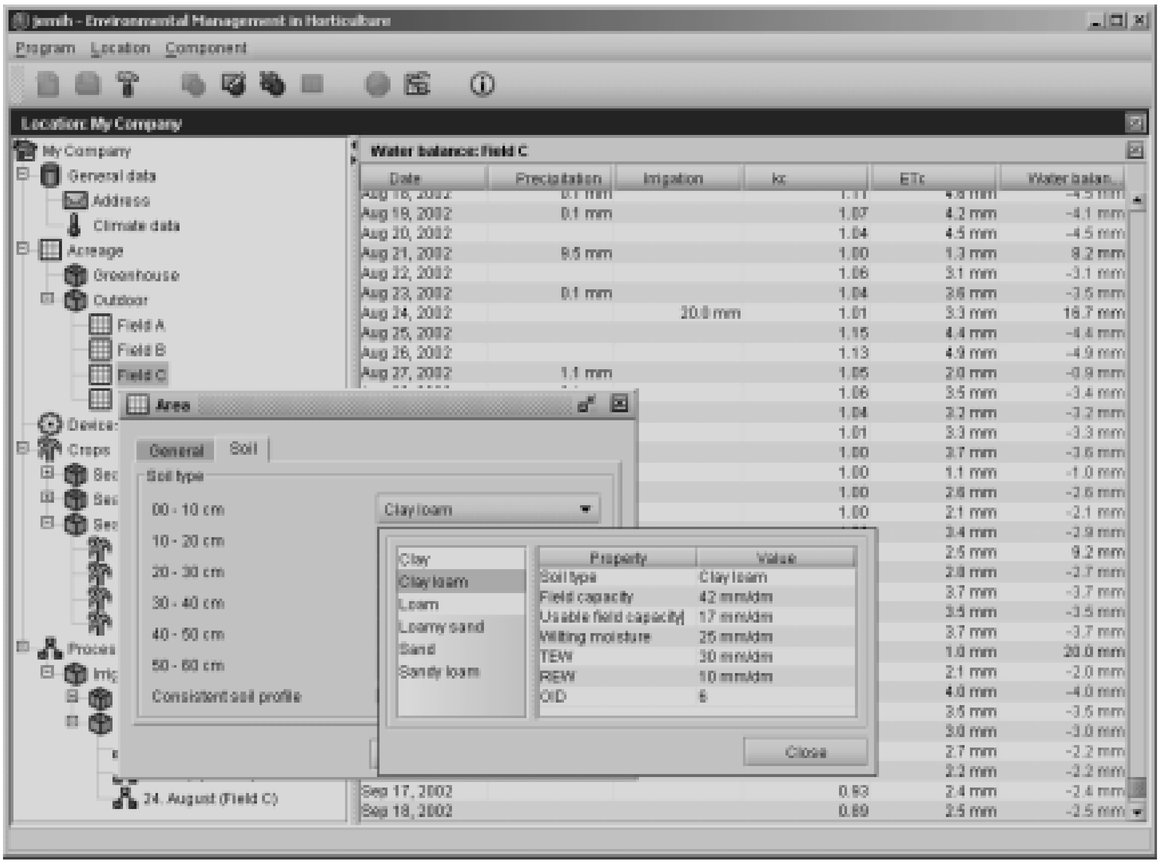

Fig. 3. Customisation of a single area object via area editor dialog: the soil properties of 'Field C' are specified by selecting predefined soil types for the soil layers. In the table on the right the water balance for 'Field C' is shown.