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FORMAL REPRESENTATION OF AGRICULTURAL ACTIVITIES THROUGH ENTITY – RELATIONSHIP MODEL

Nikola Tsaikin[1]*, Nadejda Shopova[2], Venelin Roychev[1], Theodora Srebcheva[1]

[1] Agricultural University - Plovdiv, Bulgaria
[2] Climate, Atmosphere and Water Research Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria
E-mail: tsaikin@au-plovdiv.bg

Abstract

A business process that is carried out on a limited number of types of objects can be represented formally through an Entity – Relationship model (ER model). Agricultural activities as a type of business are thematically distinct and therefore an attempt can be made to select a limited set of objects and relations to them, which would represent this thematically limited activity in a more formal form. Formalization aims to limit the properties and attributes of objects and relations to a finite and ubiquitous configuration. This finite in number allows them to be recorded in normalized databases, directed graphs and other information tools for formal representation with a view to further computational processing such as modeling, simulation or training of autonomous agents and assistants with artificial intelligence. ER model was chosen because it is simple enough and contains only identifiers and typed to a finite number of properties and attributes. The goal is to design a common configuration of properties and attributes so that the model is open to adding new objects and relations from activities in the agricultural sphere. In this article, an attempt is made to describe the production flow specifications for growing vines and pepper. Also included are objects and relations for agricultural equipment and those describing weather conditions and seasons. For the needs of training autonomous agents with artificial intelligence, concepts of human personnel, self-identification, and others are included.

Keywords: agricultural activities, Entity – Relationship model

INTRODUCTION

Activity modeling is inherent in the modern information age. Information models are created with several goals. One of them is to create a digital mirror of real processes for the purpose of more effective control and management. This is the approach of Information Systems in Business and State Administration, as well as in Content Management Systems (CMS). Another goal is to simulate real processes in order to analyze individual aspects of these processes and possibly make predictions. In both approaches, the level of detail and the resulting complexity with which real processes are reflected depends on the aspects that are the subject of interest. Thus, some characteristics of objects and activities are presented in more detail, while others are ignored.

In the object-relational model, typed objects are selected with their characteristics and the relations between them with their characteristics. The types of objects and relations are structured to a finite number. Characteristics for them are also selected and summarized to a finite number. Thus, the model acquires information integrity and becomes convenient for presentation through databases, directed graphs, etc. This article presents vows and activities from the agricultural sector, and in particular from the cultivation of vines and horticultural crops, where the use of heavy machinery is limited. The aim is to create a simulation model for such agricultural productions in order to trace the relationship between the applied agrarian activities and the state of the agricultural crop in a more discrete form. This model can also be used to control real production, but the focus of its structuring is a simulation model as a virtual environment for training an agent with artificial intelligence to be able to recognize the importance and effect of agrarian activities on the state of the agricultural crop. The agricultural crops vine and pepper have been chosen as the sphere of virtual representation. The focus is on crops for cultivation in small gardens, such as pepper. The vine is also present in small gardens outside the context of industrial production in large arrays. Thus, diversification of the objects and activities is introduced into the simulation model in order to simulate activities for a wider range of crops and to make the model more universal. Concepts and characteristics of agro-meteorological conditions, which also affect the condition of agricultural crops, are also included.

MATERIALS AND METHODS

One of the basic approaches for information representation of real processes is the Entity Relation Model (Peter P. 1976). For this purpose, it is necessary to simplify real objects by categorizing them, selecting those that are relevant to the purpose of the model and reducing them to typified objects that reflect their concept in the model. In agricultural activities, these are plants, weeds, pests, tools, workers, buildings, road infrastructure, including rows and beds along which workers and machines move, as well as many others (Santoso H. & Delima R., 2018). These objects have characteristics that are also subject to categorizing, selecting those that are relevant to the purpose of the model and reducing them to a limited set of values with discrete or quantitative parameters. An example can be a characteristic of a container for collecting fruits with a discrete characteristic of what specific or types of fruits it is about. An example of a quantitative characteristic can be indicated as how many pieces or what mass of fruits the container collects. Some of the objects can also be without characteristics, for example, a day, reflecting basic things with implicit and unchangeable properties, which, however, are relevant to the model being built.

Interactions between objects are also subject to categorization, selection, which are relevant to the purpose of the model and their reduction to a limited set of typified relations. The relation usually has a directed effect - there are always a number of objects that exert it and a number of objects on which it affects. Relations that do not have an obvious directed effect can be reduced to a two-way relation, in which both objects that it connects have the role of a causer and a victim. In agricultural activities, such interactions are loosening the surface (soil), spraying, picking off a fruit, moving in a direction or along a row or bed. The example shows that relations also have characteristics with discrete or quantitative parameters such as speed of movement or method of picking off the fruit.

One of the basic approaches for information representation of real processes is the Entity Relation Model. For this purpose, it is necessary to simplify real objects by categorizing them, selecting those that are relevant to the purpose of the model and reducing them to typified objects that reflect their concept in the model (McCarthy W. 1979). In agricultural activities, these are plants, weeds, pests, tools, workers, buildings, road infrastructure, including rows and beds along which workers and machines move, as well as many others. These objects have characteristics that are also subject to categorizing, selecting those that are relevant to the purpose of the model and reducing them to a limited set of values with discrete or quantitative parameters. An example can be a characteristic of a container for collecting fruits with a discrete characteristic of what specific or types of fruits it is about. An example of a quantitative characteristic can be indicated as how many pieces or what mass of fruits the container collects. Some of the objects can also be without characteristics, for example, a day, reflecting basic things with implicit and unchangeable properties, which, however, are relevant to the model being built.

The interactions between objects are also subject to categorization, selection, which are relevant to the purpose of the model and their reduction to a limited set of typified relations. The purpose of the model is to present agricultural objects and activities with a view to training an agent with artificial intelligence in the agronomic technology for growing agricultural crops, in particular grapevine and pepper. The training is conducted in a simulation model with virtual time and a simplified conceptual representation of the objects and activities. The approach is from learning agronomic knowledge to subsequent training for the application of knowledge in a real environment. Therefore, the activities and objects are presented in a simplified form without reaching recognition and application in a real environment.

The focus is on acquiring knowledge about the technological sequence in growing the crop, and not on recognizing real images and training skills for real manipulations. Since training artificial intelligence agents is associated with repetition, the reverse approach would require that after training for recognizing real objects, training for agricultural technologies should begin, which depend on the real seasons and phases of development of real plants, which is unjustified from a real-time perspective. In the approach using a simplified simulation model, training in agricultural technologies is carried out in virtual seasons and phases of development and with significantly less computational resources (Figure 1).

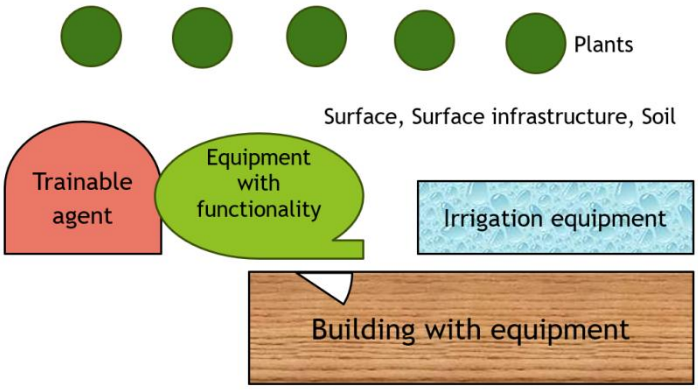

Figure 1. Schematic representation of ER model of agricultural activities with less complexity

The objects and activities on the technological maps of two agricultural crops – grapevine and pepper – have been selected for presentation (Stoev K. and all, 1970). These technological maps, as information, represent sequences of events in text form and are intended for use by agronomists and technologists (Table 1 and Table 2). They also contain quantitative and other characteristics of the activities. They do not contain information that is implied by people. They are provided by experts in the cultivation of these crops and represent formalized expert knowledge. These experts also provide information about the implied activities and production infrastructure. An agrometeorology expert provides information about weather conditions, seasons, and phenophases in the agricultural sector (Hoogenboom G. 2000, Philipova N. and all 2024).

Table 1. Excerpt from production flow for growing a vineyard.

Technological production flow for growing a vineyard in the first year, on an area of 1 dka						
№	**activity**	**Unit**	**Quantity**	**Daily allowance**	**Man/ workdays**	**equipment/ shifts**
	Planting the vines					
	…					
4	Planting with a hydrodrill				1	1
5	Making piles	number	400	1300	0,3	
6	Spring plowing - 16-18 cm	dka	1	22		0.2
7	Loosening piles after rain	number	400	1200	0,3	
8	Окопаване в реда	dka	1	2	1	
9	Cultivation	dka	1	26		1
10	Loosening piles and cleaning up dewy roots	number	400	800	0.5	
11	Second loosening of piles and cleaning of remaining dewy roots	number	400	800	0,5	
12	Preparation of spray solution	ton	0,3	4	0,1	
…	…					

Table 2. Excerpt from production flow for growing a pepper.

Technological production flow for growing Capia type pepper, medium early production, under field conditions, with drip irrigation			
№	**activity**	**Period**	**Quantity**
…			
1	Plow 25cm.	March-April	1 дка
2	Cultivation	March-April	1 дка
3	Furrowing	April-May	1 дка
4	Digging - manual	June-August	4 man/workdays
5	Weeding - manual	June-August	4 man/workdays
…			
3	Transplanting	May-June	3 man/workdays
…			

The simulation model is open in two aspects. One is for adding new objects and relations. The second is for changing the composition of the characteristics and parameters for them. The focus of the model seeks such a simplification of these objects and relations, so that they reflect the technological features and sequences in the cultivation of these crops without seeking recognition and representation of skills for working with real plants. The openness of the model allows adding information about cultivation activities and other crops with the presumption that a large part of the activities are applicable to the cultivation of multiple types of crops. Grapevine and pepper are taken as the initial assortment. Two crops are included to show the openness of the model so that it is not perceived as specialized for a particular crop.

RESULTS AND DISCUSSIONS

A significant part of agricultural activities can be simplified to the point that their implied properties remain unchanged and the same and unchanging for different crops and their phases of development. Therefore, in the present model, many of the objects and relations are left without parametric characteristics. Another feature of the characteristics is that they can take discrete and quantitative values. An example of a discrete characteristic is the degree of development of the stem and branches of the plant in stages from minimal at planting or germination, through medium to developed. The level of stratification of these stages depends on threshold values, which serve as criteria for performing activities on the plant. Quantitative characteristics, measurable in numbers with units of measurement, are also present, for example, in the activity of plowing with a parameter of depth in centimeters. Both objects and activities are provided with the possibility of having both discrete and quantitative parameters. They may also not have explicitly stated parameters, as they are considered to be implied and remain unchanged, so there is no need to keep repeated information about them. Unlike objects, relations have specific attributes for an object that initiates the action and an object that is a victim. Usually, the initiator object is the trained agent itself, and the victim object is a plant, which is why this pair of attributes may not be explicitly set.

Each object and activity have effectively meaningful parameters and if they are not explicitly set, they are applied programmatically in the programming of the simulation interactions in the model. These simulation interactions are not the subject of the article because the depth and detail of the simulated processes depends on the tasks that must be solved when designing the training of the agent with artificial intelligence. This article is limited to the approach to the formal representation of agricultural activities and infrastructure of the agricultural economy.

Another aspect is the spatial structure of the virtual environment. In order to simplify the model, spatial abstract objects such as surface and sky are assumed. The surface is important because it represents the soil and other types of surfaces, and the sky represents concepts related to weather conditions and the day/night parameter of the calendar-related concepts. In the middle is the 2-D space of the virtual reality objects. The covering surface is also a 2-D space containing objects with a pavement parameter. The sky is a single object that is common to the entire virtual environment. In this way, a pseudo 3-D space is formed of two 2-D planes for low and middle and a single object for high.

In order to present the results and demonstrate the flexibility of the model, the sample of objects and relations with their discrete, quantitative and missing implicit characteristics is divided thematically into groups.

Those that apply specifically to grapevine and pepper.

Common objects and relations that occur for both crops and are assumed to apply to other additional crops.

Objects and actions representing weather conditions.

Concepts related to the calendar and phenophases of plants.

Other objects, actions and concepts representing the infrastructure of the agricultural economy and others related to the training of the artificial agent.

As an example, specific to growing a vine is drilling a hole with a hydroboron and making a pile. Loosening the soil can have degrees, but in this case it was chosen not to. Planting the vine as a stick is specific. Plowing the row spacing has a quantitative characteristic in centimeters (Table 3).

Table 3. An excerpt on the topic of agricultural crop Grapes.

Activities	**Plant**	**characteristics**
Ploughing	Root	per crop
Loosening Soil	Stem	per crop
Harrowing in the Row	crown	per crop
Spraying	leaf	per crop
Creating a Spray Solution/ (Spray Fertilization)	fruit	per crop, degree of ripeness
Fertilization by Tillage		
Pickling		
Placing a Fruit/Stem in a Container		

For growing pepper, digging beds is typical. For the bed, it was chosen not to have a width parameter at this stage. In vegetables, we have watering, digging, weeding and transplanting. Some of these actions are performed differently for different agricultural crops, so there is a parameter for which type of plant the action is performed (Table 4).

Table 4. An excerpt on the topic of agricultural crop Pepper.

Activities	**Plant**	**characteristics**
Ploughing	Root	per crop
Loosening Soil	Stem	per crop
Harrowing in the Row	crown	per crop
Spraying	leaf	per crop
Creating a Spray Solution/ (Spray Fertilization)	fruit	per crop, degree of ripeness
Fertilization by Tillage		
Pickling		
Placing a Fruit/Stem in a Container		

In the group of common to all plants are the objects that are the components with a parameter by type (Table 5). This parameter is important in the subsequent training, when the artificial agent will be trained in image recognition. In the perspective of the study, once the agent has recognized the object, it will already be taught its function in the agricultural environment. Here are the activities that are used for many plants and in a similar way. The method may be different, but at this stage, before training, it is difficult to predict how much these differences will matter. Therefore, these activities are left without a parameter.

Table 5. An excerpt on the topic of plants and activities in general.

Activities	**Plant**	**characteristics**
Ploughing	Root	per crop
Loosening Soil	Stem	per crop
Harrowing in the Row	crown	per crop
Spraying	leaf	per crop
Creating a Spray Solution/ (Spray Fertilization)	fruit	per crop, degree of ripeness
Fertilization by Tillage		
Pickling		
Placing a Fruit/Stem in a Container		

Meteorological phenomena are represented by parameters, some of which are discrete, recognizable states, and others are measurable quantities with units of measurement (Table 6). Calendar concepts such as day, hour, season, date are important for planning activities. There are also vegetation dates that are considered under specific conditions, for example, five consecutive days with minimum temperatures above a certain limit, which is a sign of the start of specific vegetation processes.

Table 6. An excerpt on the topic of meteorological concepts and the calendar.

Meteorological Concepts	
Concept	characteristics
Soil Moisture – Measurement,	Discrete Evaluation – Dry, Normal, Humid, Wet
Air Temperatures	Current, Minimum, Maximum, Average for of the day
Illumination	discrete assessment – strong/normal/weak solar
Precipitation:	types of rain, snowfall
Earth surface	dry, moist, wet, flooded, frost, snow, icing
Sky	clear, hot, raining, snowfall, fog, cloudiness – discrete degrees
…	**…**
Calendar	
time, day, season, date, vegetation date (date with meteo-condition fulfilled, for example 5 days with minimum temperature above 5 degrees)	

In the group of other objects and relations are, for example, the container for collecting fruits with a discrete characteristic by type and a quantitative characteristic for net weight in kilograms (Table 7). Here are the objects of the infrastructure of the agricultural economy such as a building, a door lock, movement along a road, a row, a bed, and others. For the purpose of training, there are objects representing people, who may be virtually represented trainers or human workers. We can also include the concept of self-identification as "I" from the point of view of the trained artificial agent.

Table 7. An excerpt on the topic of the other concepts.

Objects and concept	**characteristics**
container	by crop, net weight (kg)
building	type, area
door	type
device for opening and closing	type
open/close	
move (towards an object, in order)	
enter/exit	
communicate with …	
person (person)	
me (self-identification)	
…	..

CONCLUSIONS

A simplified description of agricultural production has been created through typified objects, activities, concepts and a limited set of characteristics for them.

The focus of this simplified description is the creation of a virtual simulation model of agricultural production for the purpose of training a standalone artificial intelligence agent.

Representing agricultural activities in a simplified and structured form seems easy, but the challenge is to find the balance in this simplification between the conceptualization and the necessary details for the focus of this model.

The two agricultural crops presented demonstrate the openness of the model and its flexibility as a virtual simulation environment for machine learning.

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