Ontological model of a production shop

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Abstract. The paper presents an ontological model of a production shop. The necessity of such approach to domain modeling has been identified and justified. Based on the model obtained, the author suggests using it for further design of the production planning information system.

1. Introduction
The use of ontologies for modeling domains of automated information systems has been on rise recently [1 – 5]. This is due to the fact that an ontological model allows for developing a metadata model [6]. Thus, an ontology-based production planning system can be implemented for various technology industries.

In general, a business process of production planning can be described in a two-block diagram (figure 1).

![Figure 1. A business process of production planning.](image)

The first block identifies items to be produced and volumes, while the second block determines how they will be produced, namely, the production equipment, the production program, the finished product description [7].

The language of applied logic was chosen as a means to write the ontology [8 – 10].

2. Information objects

2.1. Object “Order”
An order is an input element for the system. It is characterized by a name, a list of items to be produced, and their quantity. There is also a status that determines the current stage of the order execution.

- Sort orders: \{ \} \mathbb{N} \setminus \emptyset
  The term “orders” means a set of names of orders.
- Sort ordered items: orders \rightarrow \{ \} (\text{items } I [1, \infty) \setminus \emptyset)
  The term “ordered items” matches an order and a set of pairs consisting of the item name and quantity.
- Moment \equiv I [0, \text{duration of the order execution}]
  An auxiliary term for the interval during which an order is executed.
- Sort duration of the order execution: I [1, \infty)
  A number that determines duration of the order execution.
- Sort status: (orders \times \text{moment}) \rightarrow \{\text{ready, in progress, not yet started}\}
  Any of the statuses may correspond to the order at any specific time.

2.2. Object “Schedule”
Schedule is a key element of the system that determines the progress of work. It is characterized by a name, a list of production operations with start and end date and time specified, equipment that will be used, a worker who will perform the operations, and a status that determines the stage of the production operation.

- Sort schedules: \{ \} \mathbb{N} \setminus \emptyset
  The term “schedules” means a set of names of schedules.
- Sort order being executed: schedules \rightarrow orders \setminus \emptyset
  The term “order being executed” matches a schedule and a corresponding order.
- Date \equiv \text{year} \times \text{month} \times \text{day} \times \text{hours} \times \text{minutes}
- Year \equiv I [1, \infty)
- Month \equiv I [1, 12]
- Day \equiv I [1, 31]
- Hours \equiv I [8, 18]
- Minutes \equiv I [0, 59]
  An auxiliary term for a date detailed to minute.
- Operation start date \equiv \text{date}
- Operation end date \equiv \text{date}
- Moment \equiv I [0, \text{duration of the schedule execution}].
  An auxiliary term for an interval the interval during which a schedule is executed.
- Sort duration of schedule execution: I [1, \infty)
  A number that determines duration of the schedule execution.
- Sort a list of production operations: (schedules \times \text{moment}) \rightarrow \{\} (\text{production operations } \times \text{equipment } \times \text{workers } \times \text{operation start date} \times \text{operation end date} \times \{\text{completed, in progress, not yet completed}\})
  The term “list of production operations” matches a schedule with a set consisting of a production operation name, equipment, a worker, production operation starts and end dates, and production operation status corresponding to any specific time.

2.3. Object “Equipment”
The equipment is a device whose function is to perform production operations. It is characterized by a name, a list of available production operations that this equipment can carry out with a certain duration, as well as a state that determines whether the equipment is free (does not work or works) or is not used (such equipment will not participate in the process of schedule formation).

- Sort equipment: \{ \} \mathbb{N} \setminus \emptyset
The term “equipment” means a set of names of equipment.
- Sort list of available production operations:
  equipment → {} (production operations×I[1, ∞) \ Ø)
  The term “list of available production operations” matches equipment with a set of pair consisting of a production operation name and duration of its execution.
  - Moment ≡ I[0, ∞).
  An auxiliary term for a system operation stroke.
  - Sort status: (equipment moment) → { run, idle, not used }
  Any of the statuses may correspond to the equipment at any specific time.

2.4. Object “Production operation”
A minimal unit of work unique for each detail. For example, bending of part A, resulting in part B is a production operation. It is characterized by a name, a workpiece (which is fed to the input of the production operation) and a result (which is fed to the output of the production operation).
- Sort production operations: {} N \ Ø
  The term “production operations” means a set of names of production operations.
- Sort workpiece: production operations → item
  The term “workpiece” matches the production operation with its item.
- Sort production operation result: production operations → item
  The term “production operation result” matches the production operation with its item.

2.5. Object “Worker”
An individual performing production operations using some equipment. The object is characterized by a surname, name and patronymic. Since each worker has the authority to carry out various production operations, an auxiliary characteristic “worker category” was introduced that matches each worker with his category, which is assigned a list of available production operations in this category.
- Sort workers: {} N \ Ø
  The term “workers” means a set of full names of workers.
- Sort worker category: workers → worker category,
  The term “worker category” matches a worker with his category.
- Moment ≡ I[0, ∞).
  An auxiliary term for the system operation stroke.
- Sort status: (workers X moment) → { run, idle, not used }
  Any of the statuses may correspond to the worker at any specific time.

2.6. Object “Worker category”
An object introduced for a more convenient assignment to a worker of a list of production operations that he can perform. In fact, this term can mean qualification of the worker, a profession, and so on, which makes up the totality of the production operations he performs.
- Sort worker categories: {} N \ Ø,
  The term “worker categories” means a set of names of worker categories.
- Sort list of available production operations:
  worker category → {} production operations \ Ø
  The term “list of available production operations” matches the type of worker with a set of production operations.

2.7. Object “Item”
An item is characterized with a name and a sequential list of production operations, which must be performed to manufacture an item.
- Sort items: {} N \ Ø
The term “item” means a set of names of items.

- Sort production operations for item production:
  
  items → seq (production operations)

The term “production operations for item production” matches the item with an ordered set of production operations.

3. Determination of the rules of communication among the objects

3.1. Order – Schedule

If at any specific time the order status is “ready”, then any production operations of the schedule that belongs to the relevant order must have “completed” status.

\[ (\forall M \in \text{ moments}) \ (\forall O \in \text{ orders}) \ (\forall S \in \text{ schedules}) \ \text{status} (O, M) = \text{ready} \ \& \ \text{in progress} (S) = O \Rightarrow (\forall \text{ POL} \in \text{ list of production operations} (S, M)) \ \pi (6, \text{ POL}) = \text{completed}. \]

If at any specific time the order status is “in progress”, then there is a production operation of the schedule belonging to the relevant order, with “in progress” or “completed” status.

\[ (\forall M \in \text{ moments}) \ (\forall O \in \text{ orders}) \ (\forall S \in \text{ schedules}) \ \text{status} (O, M) = \text{in progress} \ \& \ \text{order in progress} (S) = O \Rightarrow (\exists \ (\forall \text{ POL} \in \text{ list of production operations} (S, M)) \ \pi (6, \text{ POL}) \in \{\text{completed, in progress}\}). \]

If at any specific time the order status is “not yet started”, then any production operations of the schedule belonging to the relevant order must have “non completed” status.

\[ (\forall M \in \text{ moments}) \ (\forall O \in \text{ orders}) \ (\forall S \in \text{ schedules}) \ \text{status} (O, M) = \text{not yet started} \ \& \ \text{order in progress} (S) = O \Rightarrow (\forall \ (\forall \text{ POL} \in \text{ list of production operations} (S, M)) \ \pi (6, \text{ POL}) = \text{non completed}). \]

3.2. Schedule – Equipment

At the moment of production operation execution, the corresponding equipment must have “run” status, and this production operation must be included in list of available production operations of the equipment.

\[ (\forall M \in \text{ moments}) \ (\forall P \in \text{ schedules}) \ (\forall \text{ POL} \in \text{ list of production operations} (S, M)) \ \pi (6, \text{ POL}) = \text{in progress} \ \& \ \text{equipment used} (S) = \pi (2, \text{ POL}) \Rightarrow \text{status} (\pi (2, \text{ POL}), M) = \text{run} \ \& \ (\forall \text{ POL} \in \text{ list of available production operations} (\pi (2, \text{ POL})). \]

3.3. Schedule – Worker

At the moment of production operation execution, the corresponding worker must have “idle” status, and this production operation must be included in list of available production operations of the worker category where the worker belongs.

\[ (\forall M \in \text{ moments}) \ (\forall S \in \text{ schedules}) \ (\forall \text{ POL} \in \text{ list of production operations} (S, M)) \ \pi (6, \text{ POL}) = \text{in progress} \ \& \ \text{used worker} (W) = \pi (3, \text{ POL}) \Rightarrow \text{status} (\pi (O, \text{ POL}), M) = \text{run} \ \& \ (\forall \text{ POL} \in \text{ list of available production operations} (\pi (O, \text{ POL})). \]

Conclusion

The paper presents a mathematical model of the domain ontology of a production shop to the extent necessary for production planning. It is assumed that such model will be used to create process control systems.

At the same time, availability of a mathematical model of ontology has an independent significance, since it formally defines all the terminology used to ensure unambiguous interpretation of meaning of all the terms.

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