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Research Article
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Activity Ontology of Water Production Company

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Abstract

The key success of a business process is the ability to manage between processes within an enterprise and between enterprises. To remain competitive, enterprises must become increasingly agile and integrated across their functions. Activity ontology plays a critical role in this integration, enabling better designs for enterprises, analysis of their performance, and management of their operations. The goal of this paper is to create an activity ontology for water production processes that has the ability to deduce answers to queries that require relatively shallow knowledge of the domain. This activity ontology will provide a sharable representation of knowledge that minimizes ambiguity and maximizes understanding of the production activities. This kind of representation is of importance because it will be able to provide sophisticated support to automated decision making; it does not only answer queries with what are explicitly represented in the Knowledge Base, but also answer queries to what is implied in the Knowledge Base. The project was implemented using Prolog, a logic programming language and it was tested by posing a set of competency questions.

Keywords: Activity Ontology; Competency questions; Knowledge Base; Formal Representation

Introduction

An activity is the basic transformational action primitive with which processes and operations can be represented; it specifies how the world is changed [1]. Thus in this paper, the focus is on how the production activities of water production company can be modeled. The activity ontology for the production activities would provide a framework that would break down the steps involved in the different activities and the time interval for each activity. In enterprise modelling, we want to define the actions performed within an enterprise, and define constraints for plans and schedules which are constructed to satisfy the goals of the enterprise. This leads to the following set of informal competency questions.

a. Temporal projection: Given a set of actions that occur at different points in the future, which are the properties of resources and activities of different intervals.

b. Planning and Scheduling: What sequence of activities must be completed to achieve some goal? At what times must these activities be initiated and terminated?

c. Time-Based Competition: We want an ontology that minimizes the cycle time for a product. This is essentially the task of finding a minimum duration plan that minimizes action occurrences and maximizes concurrency of activities.

Activities are defined to occur over intervals of time and cannot be reduced to some set of properties holding at instantaneous points in time.

In an enterprise, activities take place over time. These time points can be point based, interval-based or point-interval-based. In this paper, we want to see how practicable are the Allen's interval temporal logic of Actions and Events using Water Production Activities.

This paper therefore aims at developing activity ontology in form of knowledge representation that includes facts and axioms that support deduction for the activities of water production, the ontology will be able to deduce answers to some given queries. These queries are the common sense queries that require the knowledge base system to have extensive knowledge and reasoning capabilities.

Ontologies are widely used as technique for representation and reuse of knowledge. Ontology can be viewed as a shared conceptualization of a domain that is commonly agreed to by all parties. It is defined as 'a specification of a conceptualization [2]. 'Conceptualization' refers to the understanding of the concepts and relationships between the concepts that can exist or do exist in a specific domain.

The primary goals for developing ontology is not only to enable reuse of domain Knowledge but also to share common understanding of the structure of information among people or software agents, to make domain assumptions explicit, to separate domain knowledge from the operational knowledge and to analyze domain knowledge in an enterprise context, they reflect the relevant knowledge based on enterprise-specific concepts and their relations. This activity ontology can be considered as building blocks for demand-oriented information supply in networked organizations.

Drinking water can be produced from any natural sources like ground water, lakes and rivers (surface water) or sea water. Drinking water standard are set by the world health organization/NAFDAC. Drinking water must be free of suspended solids, microorganism and toxic chemicals. The quality of drinking water is assessed not only in terms of health but also in terms of taste. One of the solutions for improving the taste of water is to reduce the amount of environmental organic materials, which are difficult to eliminate with traditional treatment processes due to their high solubility. The more organic materials there are in water the higher the microbiological risk and the more necessary the chlorination treatment becomes, organic materials and chlorine jointly deteriorating the taste of water in the supply systems, the easier it is to reduce chlorination and therefore unwanted effects, not only in terms of taste but also with regard to disinfection by-product. Water properties differ from one area to another, some of these properties are; Hardness, Alkalinity, pH level, Conductivity etc. these properties differ from one area to another area and any drinking water produced must be in accordance with the NAFDAC specifications.

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Literature Review

Ontology as a specification of conceptualization is defined by logical theory, axioms of which constrain predicate interpretations. Nikola Guarino uses notions of domain space and conceptual relationships. Several projects are known that create ontologies to define a given subject domain and share this knowledge among users for more coordinated interaction in domain.

TOVE [3] and Enterprise [4] create ontologies for commerse and production organization, CIDOC [5] develops ontology for museums and cultural heritage, PHYSSYS [6] creates an ontology in the area of physical systems. The project SYNTHESIS uses ontologies for semantic interrelating of object-oriented specifications.

Project Ontoseek and Plinus use ontologies for information retrieval. There are many projects where ontologies help to detect similarities and redundancies in natural language information [7]. Ontologies are used for context definition in a subject domain. Determination of exact difference between contexts helps to solve a problem of viewing onto an information resource from another context or changing of resource moving from one context to another [8]. Using shared ontologies, establishing correspondence of data to ontological definitions; enhancing ontologies for new tasks allow to achieve correct interoperation between different information systems [9].

The web needs ontologies for relating web-information to concepts of ontologies. The project SHOE [10] proposes to support HTML-pages by additional tags, which relate the information to ontological definitions. The TOVE Ontology currently spans knowledge of activity, time and causality, resources and more enterprise oriented knowledge such as cost, quality and organization structure. The TOVE Testbed provides an environment for analyzing enterprise ontologies; it provides a model of an enterprise and tools for browsing, visualization, simulation and deductive queries. The goal of the TOVE Enterprise modelling project is to create a common sense Enterprise model. By common sense we mean that an enterprise model has the ability to deduce answers to queries that require relatively shallow knowledge of the domain.

CIMOSA (Computer Integrated Manufacturing Open System Architecture)

CIMOSA incorporate an event-driven, process based modelling approach with the goal to cover essential enterprise aspects in one integrated model. The main aspects are the functional, behavioural, resource, information and organizational aspect. For each of the aspects, modelling constructs are available. This enables to model the aspects of business processes independent from each other. CIMOSA provides a formal language for the modelling, which is specified in BNF form.

Furthermore, CIMOSA aims at the execution of business processes also, not only the modelling of those. The goal is to drive an information infrastructure with the processes modelled.

PERA (The Purdue Reference Architecture)

PERA was developed as an endeavor in enterprise modeling for a computer-integrated manufacturing (CIM) factory by the Purdue Laboratory for Applied Industrial Control at Purdue Laboratory University [11]. The functional descriptions of the tasks and functions of the enterprise are divided into two major streams: (1) Information (including decision and control) and (2) Manufacturing, or customer service.

Classes of models for ontology construction and reasoning

Ontological modelling in information technologies has undergone considerable evolution. Models and languages used for ontology construction and reasoning can be classified as follows.

Verbal models

Informal linguistic models are often used for specification of ontologies [12]. In such models ontological concepts are defined by verbal definitions like in an explanatory dictionary. Some kinds of basic relationships may be established between concepts. A glossary of terms in some subject domain, a thesaurus with its concepts and relationships defining natural language terms may be considered as ontologies.

Logic-Based models

In contract to verbal models, logic based ontologies are defined formally and have an ability of formal reasoning. One of the first logic-based ontological models was Ontolingua [13]. Predicative expressions in Ontolingua are represented in the KIF language, which is based on the first order logic. KIF is highly expressive and due to that it is not tractable for automatic inference. Development of ontologies in this model is regulated by special technique for adding of unambiguous specifications [14]. Ontolingua has been intended as an intermediate language for heterogeneous ontologies interchange.

Ontological model uses a tran model as its basis. The open knowledge Base connectivity (OKBC) API is considered as a key enabler in the distributed ontology repository architecture. The OKBC model serves as an inter-lingua for ontology that is being communicated using OKBC.

Ontology interchange language, OIL is the first ontology representation language in W3C standards that is properly grounded. It is an evolution of existing proposals such as OKBC, XOL, RDF (Resource Description framework). OIL is the first web-based representation language intended for ontology definition with the formal semantics and reasoning services provided by description logic.

Structural (Object) models

Several approaches are known to apply structural (Object) data models to define ontologies. A mediator ontological language (MOL) may depend on a subject domain and is to be defined at the media for consolidation phase. On the other hand, for different information sources different ontological models (languages) can be used to define their own ontologies. Reversible mapping of the source ontological models into MOL is needed for information sources registration at the mediator.

Hybrid models

To enrich an expressive power of the ontological model, there might be a need to use facilities of verbal, logic-based or structural models in one and the same ontology. For instance, this project uses a hybrid model. The ontological model has verbal facilities making possible to define ontological or glossary concepts, classifier categories. At the same time, it is defined as logic-based type.

Methods and Formal Representation

Actions and events in interval temporal logic

In order to adequately represent actions and events, one need an explicit temporal logic [15] and that approaches with weaker temporal model such as state spaces (e.g. STRIPS-based approaches) and the situation calculus, either cannot handle the problems.

Properties of actions and events

Properties of action and events those are essential to any general representation:

a. Actions and events take time, while some events may be instantaneous, most occur over an interval of time – During this time, they may have a rich structure. Because events are extended in time, different events and actions may overlap in time and interact.

b. The relationship between actions and event and their effects is complex. Some effects become true at the end of the event and remain true for some time after the event. Other effects only hold while the event is in progress. Other effects might start to hold sometime after the event has started and stop holding before it finishes.

c. Actions and events may interact in complex ways when they overlay or occur simultaneously.

d. External changes in the world may occur no matter what actions an agent plans to do, and may interact with the planned actions.

e. Knowledge of the world is necessary incomplete and unpredictable in detail, thus prediction can only be done on the basis of certain assumptions.

In this paper, the following steps are carried out;

a. Purpose identification and requirement specification-concerns to clearly identify the ontology purpose and its intended uses, that is, the competence of the ontology. To do this, we use competency questions (Figure 1).

b. Ontology capture, the goal is to capture the domain conceptualization based on the ontology competence. The relevant concepts and relations were identified and organized.

c. The formalization activity aims to explicitly represent the conceptualization captured in a formal language. In this project, first order logic is the preferred formalism, since it embeds less ontological commitments.

d. Finally, the ontology was evaluated using Prolog to check whether it satisfies the specification requirements and ontology competence. It should be noticed that the competence questions plays an essential role in the evaluation of the completeness of the ontology, especially when considering its axioms (Figure 2).

Language definition

The language used is the interval temporal logic of Action and Events, subset of first order predicate calculus. Standard symbols for quantifiers are used; universal (V) and Existential (Ǝ).

The connectives used are;

Negation	(˥)
And	(Λ)
Or	(V)
Implies	(→)
Conditional implication	(↔)

Time relations used are;

Meets (i, j) - Interval 'i' meets interval 'j'.

Before (i, j) – Interval 'i' is before interval 'j'.

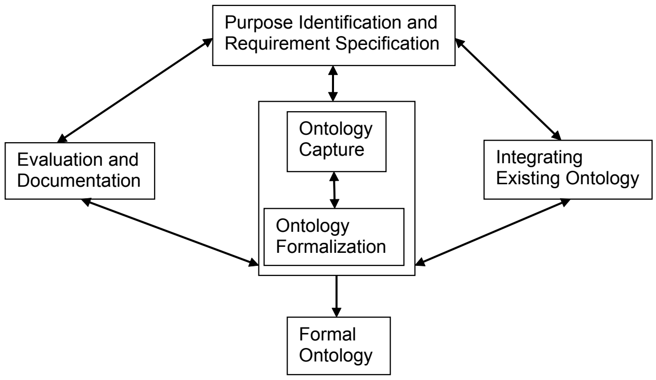

Figure 1: Steps in the ontology development process.

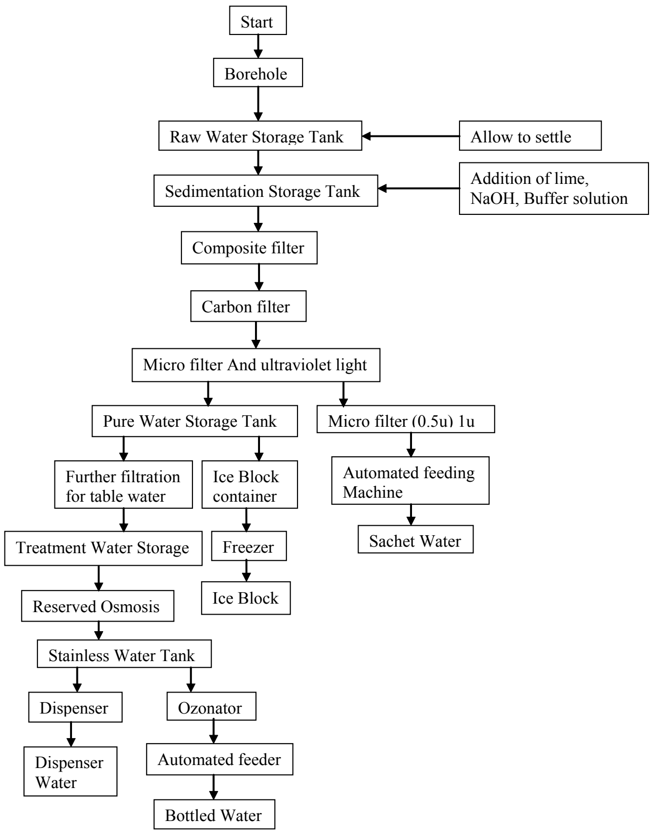

Figure 2: Water Production Flowchart.

After (i, j) – Interval 'i' is after interval 'j'.

Equal (i, j) – Interval 'i' is equal to interval 'j'.

Overlaps (i, j) – Interval 'i' overlaps interval 'j'.

Cover ((i, j, k) – Interval 'i' covers interval 'j' and 'k'.

Specification in first order Logic – Axioms

A. $V\ t1,t_2,e\ Pump(st_1,st_2,e) \Leftrightarrow Level(st_1,full,Pre2(e) \wedge Level(st_2,empty,Pre2(e)) \wedge \wedge e_1,e_2\ Open\ tap(st_1,e_1) \wedge water\ flows(st_1,st_2,e_2) \wedge Level(st_1,empty,eff1(e)) \wedge Level(t_2,full,eff2(e)) \wedge Meets(time(pre1(e_l)),time(pre2(e))) \wedge Meets(times)$

(pre1(e)),time(e_1)) Λ Overlap(time(e_1),time(e_2)) Λ Cover(time(e), time(pre1(e)),time(e_2)).

Water is pumped from storage tank (st_1) to storage tank (st_2) if st_1 is full and st_2 is empty, these are the two preconditions. And there exist activities (e_1) and (e_2) such that e1 is the opening of tap for st1 and e2 is the process of water flowing from st1 to st2 and the effect of these is that the level of st1 will now be empty while that of st2 will be full. The time relations are as shown below.

B. ***V t,e Treatment(e,t) ⇔ Ǝe_1,e_2,e_3 Sedi(e_1,pre1(e),t_1) Λ Filt(e_2,pre2(e),t_2) Λ Sterili(e_3,(pre3(e),t_3) Λ Before(t_1,t_2) Λ Overlaps(t_2,t_3) Λ Cover(t_1,t_2,t_3).***

For all water treatment, there exist sedimentation, filtration and sterilization.

B1.V st_2,t,e Sedime(st_2,t,e) ⇒ Λe_1,e_2,e_3 Add($CaCO_3$,st_2,e_1,t_1) Λ Dissolve($CaCO_3$,st_2,t_2) Add(NaOH,dt$_2$,e_2,t_3) Λ Dissolve(NaOH,st_2,t_4) Λ Add(bufsol, st_2,e_3,t_5) Λ Dissolve(bufsol,st_2,t_6) Λ Meets(t_1,t_2) Λ Before(t_2,t_3) Λ Meets(t_3,t_4) Λ Before(t_4,t_5) Λ Meets(t_5,t_6) Λ Cover(t,t_1,t_6).

For Sedimentation to occur, there is going to be addition of Calcium Carbonate, which will take time interval t_2 to dissolve, Sodium Hydroxide will take time interval t_4 to dissolve and Buffer Solution will take time interval t_6 to dissolve .The time relation is as shown.

B2. V t, e Filt_ster(e, t):- Ǝe_1, e_2, e_3 Open_tap(st_2,e_1,t_1) Λ Waterflows(st_2, comp_filter,t_2) Λ Waterflows (comp_filter, carbon_filter,t_3) Λ Waterflows (carbon_filter, micro filter,t_4) Λ Waterflows (micro filter, ultraligth,t_5) Λ After(t_1,t_2) Λ Overlap(t_2,t_3) Λ Overlap(t_3,t_4) Λ Overlap(t_4,t_5) Λ Overlap(t_5,t_6) Λ Cover(t,t_1,t_6).

For filtration and sterilization to occur, sedimentation tank st_2 will be opened for water to flow from it through composite filter, then through carbon filter and then through micro filter, for the process of filtration. After the water has been filtered, it needs to be sterilized by flowing through the ultraviolet light. The time interval is as shown.

A. ***V e,t Bottlemaking(e,t) Λe_1,e_2,t_1,t_2 Heating(e_1,t_1) Λ Blowing(e_2,t_2) Λ Meets(t_1,t_2).***

For all bottle making activities, there exists heating and blowing activities, and the two activities meet.

C1 V e,t Heating(e,t) ⇔ Λp,m,e_1,e_2,t_1,t_2 Preform(p) Λ Heatingmachine(m) Λ Heatup(e_1,m,t_1) Λ Pass(p(s),m,e_2,t_2) Λ Remove(p(s),m,t_3) Λ Meets(t_1,t_2) Λ Meets(t_2,t_3) Λ Cover(t,t_1,t_3).

For all heating activity, there exists perform of a particular size and heating machine such that the heating machine is heated within time interval t_1 and immediately perform is passed through the heated machine. The end product is the heated perform.

C2 V e,t Blowing(e,t) ⇔ Ǝp,b,m,e_1,e_2,t_1,t_2 Heated_preform(p)) Λ Blowing_machine(m)) Λ Bottles(b) Λ Set-mould(s,m,e_1,t_1) Λ Put_in (p(s),m,t_2) Λ Press(m,t_3) Λ Remove(b,s,m,t_4) Λ Meets(t_1,t_2) Λ Meets(t_2,t_3) Λ Meets(t_3,t_4) Λ Cover(t,t_1,t_4).

For all blowing process, there exists heated perform and blowing machine ,such that mould of size(s) is set into the blowing machine ,and the heated perform is put inside the blowing machine which in turn is being pressed. The end product is the bottle.

D. V e,t Satchet Water Production(e,t) ⇔ Λe_1,e_2,e_3,e_4,e_5,e_6 Set(f,a,e_1,t_1) Λ Pass_through(f,u,e_2,t_2) Λ Fill(a,f,e_3,t_3) Λ Seal(a,f,e_4,t_4) Λ Cut(a,f,e_5,t_5) Λ Packs(w,s,n,e_6,t_6) Λ Before(t_1,t_2) Λ Overlap(t_2,t_3) Λ Overlap(t_3,t_4) Λ Overlap(t_4,t_5) Λ Overlap(t_5,t_6) Λ Cover(t,t_1,t_6).

For every sachet water production, there exists sub activities; set, pass through, fill, seal, cut, and pack. Film (f) is set into automated machine (a) and the film is passed through the ultraviolet light to be sterilised. The function of the automated machine is to fill, seal and cut. The factory workers (w) pack the sachet water (s) in number of 20 inside the packing nylon (n). The time relation is as shown.

D. V e,t Bottle_Water(e) ⇔ Ǝe_1,e_2,e_3,e_4,e_5,e_6 Further_treatment(e_1,t_1) Λ Bottlewashing(e_2,t_2) Λ Feeding(e_3,t_3) Λ Capping(e_4,t_4) Λ Labelling(e_5,t_5) Λ Auto_pack(e_6,t_6) Λ Meets(t_1,t_2,t_3,t_4,t_5) Λ Cover(t,t_1,t_6).

For every bottle water activity, there exists subactivities ; further treatment , bottle washing , feeding , capping , labelling and autopack.

E1 V e,t Further_treatment(e,t) ⇔ Λm,o,r Microfilter(m) Λ Ozonator(o) Λ ReverseOsmosis(r) Λ Waterpass_through(m,t_1) Λ Waterpass_through(o,t_2) Λ Waterpass_through(r,t_3) Λ Overlap(t_1,t_2,t_3) Λ Cover(t,t_1,t_3).

For all further treatment activity, there exists micro filter, ozonator and reverse osmosis, water pass through each of these for further treatment.

E2 V e,t Bottle_water_ process(e,t) ⇔ Ǝe_1,e_2,e_3 Insert(f,c,a,t_1) Λ Arrange(f,b,w,t_2) Λ Wash(w,b,t_3) Λ Feed(j,b,t_4) Λ Cap(k,b,t_5) Λ Label(f,b,t_6) Λ Arrange(f,b,v,t_7) Λ Packing(v,b,t_8) Λ Before(t_1,t_2) Λ Meets(t_2,t_3) Λ Overlap(t_3,t_4) Λ Overlap(t_4,t_5) Λ After(t_6,t_5) Λ After(t_7,t_6) Λ Meets(t_7,t_8) Λ Cover(t,t_1,t_8).

Bottle water process involve insertion of covers(c) by factory workers (f) on the automated capping machine (a), arranging bottles (b) on the washing machine (w) and washing of these bottles by the washing machine, feeding of these bottles by the feeding machine (j), capping of these bottles by automated capping machine (k), labeling by the factory worker and packing of these filled bottles by the automated shrink machine (v).

F V e,t Dispensed_water_production(e,t) ⇔ Ǝd,f,t Dispenser(d) Λ Factory_worker(f) Λ Treated_water_tank(t) Λ Fill(f,d,t,t_1) Λ Cap(f,d,t_2)Λ before(t_1,t_2)Λ Cover(t,t_1,t_2).

For all dispenser water production, there exists raw material, dispenser, factory worker and treated water tank, the factory worker fill the dispenser from the treated water tank and the factory worker then cap the dispenser. The time interval is as shown.

Results and Discussion

Informal competency questions

Motivating scenarios are problems which are encountered in the specified industry. Given the motivating scenario, a set of queries will arise. TOVE consider these queries to be requirements that are in the form of questions that ontology must be able to answer. These are the informal competency questions, since they are not yet expressed in the formal language of the ontology.

Ideally, the competency questions should be defined in a stratified manner, with high level questions requiring the solution of lower level questions. These competency question do not generate ontological commitments, rather they are used to evaluate the ontological commitment that have been made.

Competency questions

What steps are involved in a particular process?

Which activity comes first?

What is the total time taken for a particular process to complete?

What are the low level activities involved in achieving the high level activity?

What is the time interval for each low level activity?

What are the raw materials used for each activity?

The window below shows the available set of options, these options have been linked for the system to answer each competency question (Figure 3).

To know about pumping process, choose option 1 and press enter, the window shows the activities involved and time interval for each activity (Figure 4-6).

To know about the processes involved in sachet water production and the raw materials involved, enter option 4 and press enter (Figure 7).

Conclusion

Activity ontology has been built using the water production company. It achieves the principal aim of capturing domain knowledge in a generic way, and it provides a shared understanding of the domain, which may be reused and shared across applications and groups. It provides a standard ontology for water production Company, thereby minimizing ambiguity and maximizes understanding of the production activities. Also the set of competency questions developed and tested showed that it would effectively serve as the core of an organization. In addition, it also helps in the storage of water production knowledge for those people that have no experience in the field.

```
Prolog Inference Engine - [Dialog]
File  Edit  Engine  Window  Help
Ready
Use OnlineHelp to see descriptions ...
To load example files choose File\Consult menu entry ...
Type your predicate calls here like
write('Hello world!'). <- Set Caret here and press Enter
Consulted from: C:\Users\Bola Oyekunle\Desktop\pie\pie\production.pro
begin
Choose the option of the process you would like to know about
1 Pumping
2 Water Treatment
3 Bottle Making
4 Sachet Water Production
5 Bottled Water Production
6 Dispense Water Production
7 Quit
Enter Option
```

Figure 3: Options Interface.

```
Enter Option
1
Pump
________
Pumping Process takes place between time interval 1200 , 1230.
It has two preconditions
1.Checking the level of storage tank1
2.Checking the level of storage tank2
The next step is to open tap for water to flow from storage tank1
to storage tank2.
The flowing process takes place between time interval 1203 , 1230.
At the end of time interval 1203 , 1230, level of storage tank1 is empty
at time instant 1230 , 1230.
The level of storage tank2 is full at time instant 1232 , 1232.
The next step after this is Water Treatment .
No solutions
```

Figure 4: Interface showing pumping process.

```
Choose an option
1 Overall Process
2 Sedimentation
3 Filtration and Sterilization
1

There are two stages
1.Sedimentation : Sedimentation takes place between time interval
1235 , 1514
It involves addition of
A. caco3 into tank2 between interval 1235 , 1237
 and this will dissolve in tank2 between interval 1237 , 1340
B.naoh into tank2 between interval 1341 , 1345
 and this will dissolve in tank2 between interval 1345 , 1359
C. _ into tank2 between interval 1400 , 1405
 and this will dissolve in tank2 between interval 1405 , 1514

2. Filtration and Sterilisation : here sedimented water from tank2 will pass through three different filters
a. composite_filter within the time interval 1526 , 1500
b.carbon_filter within the time interval 1530 , 1510
c.micro_filter within the time interval 1540 , 1520
d.  Finally water will be sterilised by passing through ultra_light within time interval 1551 , 1531
```

Figure 5: Interface showing water treatment activities.

```
Bottle Making
________
bottle is made from the raw material preform,
of particular size_s,
within time interval 1830 , 1936.
The first stage is to set mould of a particular size_s into blowing_machine,
within time interval 1830 , 1850.
The second stage is to heat up the heating_machine,
within the time interval 1900 , 1930.
The next stage is to pass preform of a particular size_s,
into heating_machine within time interval 1930 , 1932.
The fourth stage is to remove preform of a particular size_s,
from heating_machine within interval 1932 , 1933.
The next step is to immediately put preform of a particular size_s,
removed from heating_machine into ,
blowing_machinewithin time interval 1933 , 1934.
preform still inside blowing_machine press blowing_machine,
within time interval 1934 , 1935.
The end product is The bottle of size_s,
within interval 1935 , 1936.
True
```

Figure 6: Interface showing bottle making activities.

```
4
Sachet Water Production
________
sachet_water is the end product of Satchet Water Production
automated_filling_machine is a machine that ;
fill
seal and
cut
The raw material used is film The time interval taken to producesachet_water using a pack of film is 2000 , 2148
The first stage is to set pack of film into automated_filling_machine within interval 2000 , 2030
The next stage is to sterilise film by passing it through ultra_violet_light within time interval 2040 , 2140
Next, automated_filling_machine will now fill film within time interval 2042 , 2142
The next stage is  that automated_filling_machine will seal film within interval 2044 , 2144
automated_filling_machine will then cut film into equal sizes  within time interval 2046 , 2146
The end product of this production is sachet_water within time interval 2047 , 2147
The final package is done by the factory_workers using nylon
True
```

Figure 7: Sachet water production activities.

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