Modelling Traceability in the Forestry Wood Supply Chain

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***Abstract*—Equivalent of €5 billion of wood raw material is going to waste in Europe. The reason is that information regarding the raw material is not available throughout the system. An automatic traceability system makes it possible to use the raw material information throughout the forestry wood production system. The RFID-technology can achieve automatic traceability by enabling us to connect the physical world objects with their virtual counterparts. This traceability system needs to have a temporal data model to support tracking of the raw material and monitoring of the processes. In this paper, that data model for the traceability system of the forestry wood supply chain is presented.**

I. Introduction

The forestry wood supply chain can be defined as a network of autonomous or semiautonomous business entities collectively responsible for procurement, manufacturing and distribution activities of the product. In the supply chain different business entities are highly dependent on each other. The performance of the supply chain depends highly on the performance of each business entity. One pressing problem in several supply chains is the non-optimal use of resources. This can be solved by introducing the real-time traceability solution for the material flow.

The forestry wood supply chain has a concern with allocating the right raw material for the right final product. This is caused by the following facts: Firstly, the supply chain is not continuous and consists of many steps. Secondly, the biological raw material is very complex. Accurate data is collected during every step but most of this data is lost later in the supply chain. The core problem is to acquire product and production information for each item and enable utilisation of this information through the supply chain.

Nowadays wood is treated as bulk material in the forestry wood supply chain and it has to be graded in the final stages of the production process to find out if it meets the demands of the customer. However, we can define quality attributes needed for different end products. By using the RFID technology to identify the individual objects in the supply chain we can enable the pull model for the wood material.

Traceability improves control over the flow of wood and the follow-up of the processes of the supply chain. The more accurate and complete information about the wood origin and the processes allows big improvements in the supply chain. For example in the window frame manufacturing we can maximise the yield if we minimise the amount of knots in the boards. This can be achieved by selecting trees with high internode length to be harvested and directed to the window frame manufacturer.

There are some previous researches made about RFID data modelling. Liu & Wang developed a model in [1] and it was developed further in [2-4]. Nguen et al. presented their model which includes business transactions in [5]. Harrison presented categories of RFID data and some query examples in [6]. However, these models do not take into account the specific nature of wood products production where the raw material evolves throughout the supply chain.

In this work the data model presented in these studies is extended to be able to handle the evolution of the wood objects. The presented model also includes the connection between the process parameters of the supply chain and the flow of the wood objects. This enables the traceability of the processes.

II. Modelling forestry wood supply chain

The data concerning the raw material flow in the forestry wood supply chain is by nature temporal and dynamic. The individual associated data is collected throughout the supply chain using smart identification techniques. The individual associated data is a data concerning all the wood objects that have been used to create an upgraded product. For example if the upgraded product is a window frame the evolution path for the window frame is tree(s), log(s), board(s), pieces of board.

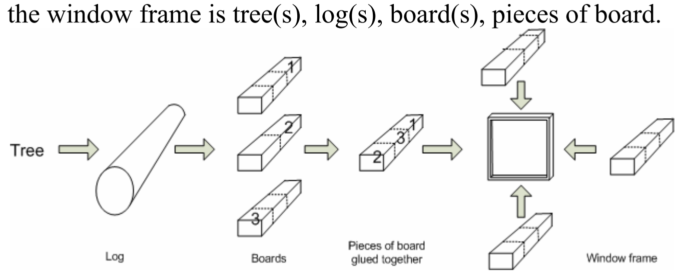

Fig. 1. Traceability Challenge.

In the forestry wood supply chain information can be divided into dynamic and static information. Static information is information about processes, locations and entity types. Dynamic information is information about individual objects (tree-log-board-upgraded product) and process measurements (energy used, waste produced).

When researching different forestry wood supply chains we can detect the following entities that can be used to model all the supply chains which are examined: the object, the process, the observation and the measurement.

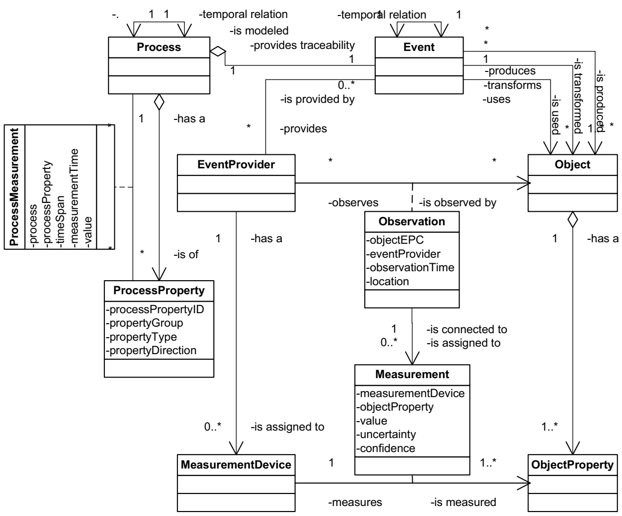

FIG. 2. MODEL OF FORESTRY WOOD TRACEABILITY SYSTEM

The object entity includes both separate objects such as tree, log, board and upgraded product and containment objects like package, kiln patch. The objects have also the parent-child relation for wood object evolution. For example a board is sawn from a log. All the objects have also some properties like moisture and a location. The purpose of the system is to keep track of the locations of the objects. The location can be either geographic (coordinates) or symbolic (the warehouse, the route between A and X). When keeping track of the changes in the system we need to take into account the ramification problem and the qualification problem. The ramification problem deals with the constraints of an action and the qualification problem is used to determine the constraint(s) in which the action is allowed to be executed.

Every distinguishable step in the forestry wood supply chain is called a process which is modelled with event(s). A process has a specific set of properties. There are three types of process properties: informational, input and output properties. The informational properties are not consumed in the process. The input and output properties can be either economical or environmental. Traceability allows connecting these process properties to individual objects and thus we can define all the costs and environmental effects concerning the life cycle of the individual objects. We distinguish three different types of events in the forestry wood supply chain – Usage, Produce and Transform. The usage type of the event uses a wood object. The produce type of the event produces a wood object and the transform type of the event changes the property values of the wood object. The relations between processes and events are modelled with the relations that were defined by Allen [7]. They define the relation between two time intervals and are: Equals, Precedes, Meets, Overlaps, Finishes Contains, Starts and their inverted relations. They cover all the temporal relations between two events.

The meaning of traceability is to track the dynamic interactions between processes and objects, e.g. to track the change of the location property of an object in the supply chain. This is done with observations. An observation is generated when an object is detected with an event provider. An observation is connected to a measurement that is needed to be able to track the changes of other object properties like moisture. For example: In the log reception the log is observed with an RFID-reader and it is measured with a 3-d scanner, log reception event is then sent to the database.

III. USING THE TRACEABILITY INFORMATION

The traceability information improves control over the flow of wood and the follow-up of the processes of the supply chain. For example, the traceability system stores the information about wood object relations in the following tables.

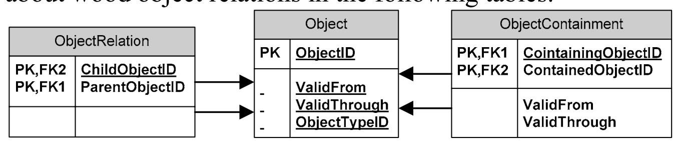

FIG. 3. OBJECT AND OBJECT RELATIONS

The traced wood objects and their life times are stored in the table Object. The table ObjectRelation is used to store object parent/child relations and the table object containment is used to store containment relations. By using these tables the user can fetch the evolution path of the wood object by the recursive query. For example in the Oracle database:

```
SELECT childObjectID
FROM ObjectRelation
START WITH childObjectID = 'EPC_CODE'
CONNECT BY PRIOR parentObjectID = childObjectID
```

By using the wood object traceability data together with the process property measurements the user can calculate the economic and environmental key performance indicators of the process. For example, the user can calculate the energy used in the drying process and correlate it to the amount of boards dried.

```
energy used = SELECT Value FROM ProcessMeasurement
        WHERE   process = 'KilnDrying' AND
                processProperty = 'EnergyUsed' AND
                trunk(measurementTime) = to_date('01-JAN-2008')
boards dried = SELECT count(objectEPC) FROM Observation
        WHERE   location = 'DryingKiln' AND
                trunc(observationTime) = to_date('01-JAN-2008')
```

In this work we extend the RFID data model so that it supports tracing of the evolution of the wood objects and connects the process information to the product information, thus allowing the users to calculate environmental and economical key performance indicators for the supply chain.

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