Conceptual Modeling of the Disassembly Processes

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Abstract: Due to awareness of the product life cycle's impact on the environment, manufacturers have started to embrace the concept of resource recovery systems as an intermediate solution to the environmental problem. The disassembly process is the main stage in recycling of the manufactured products. Disassembly promotes reuse, recycling, material and energetically recovery. In this paper we present some methods for modeling the automatically disassembly process in view of recycling.

Keywords: disassembly, modeling, control, object oriented Petri nets;

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1. Introduction

As a result of the development of the socio-economic life in the second half of the last century, the world was faced with a vital problem: how can we maintain a continuous development without harming the environment of our planet?

Since the success of industrial revolution at the turn of the century, technology has been consistently revolutionized. Technological development, diminution of the natural resources, exponential growth of human population, raise of consumer demands, waste of disposal, are factors that had contributed to an accelerating rate of pollution and degradation of the natural environment. That's why manufacturers are obliged to take into account the effects of their actions on the environment (Filip, Barbat,1999). There are more stringent regulations that call upon companies to be environmentally responsible, to search better methods to reuse and recycle their products. Nowadays, the designers are concerned about the destination of the products at the end of their life. Producers are obliged to design and manufacture their products in order to facilitate their recycling.

2. Disassembly: main stage in recycling

Product life cycle is a concept, which refers to the product itself as well as its components.

The process of conception manufacturing using used to work in open loop. Now we have to take into account a new stage that closes this process: **recycling.**

To recycle manufactured goods, several types of valorization are available: reuse of components, valorization by treatment of materials in order to reuse them or energy recovery by incineration. Disposal, which is the last solution, is done only if the other possibilities are impossible. The choice between these different types of valorization determines recycling process. These types will allow defining *end-of-life destinations* for components of manufactured goods.

Different recycling loops are different approaches of the process. The simplest approach is that of dismantling the product. By applying dismantling, a discarded good can be broken down faster and with small costs. In this case more pure fractions can be obtained with less efforts.

This simple approach exploits the value of the raw material. It doesn't take into account the functional value of the product or of its components.

To regain the functional values a recycling process is needed so that it may minimize the destroying effects on the product. This means to reuse, refurbish and capitalize on the components of the used product in order to remanufacture a new one. Re-manufacturing is an economical form of reusing, since its objective is to maximize the value of repaired parts and to minimize the disposal quantity. Central to re-manufacturing is the **disassembly process** that decomposes a product into parts and/or subassemblies.

In Figure 1, different loops of product life cycle are represented.

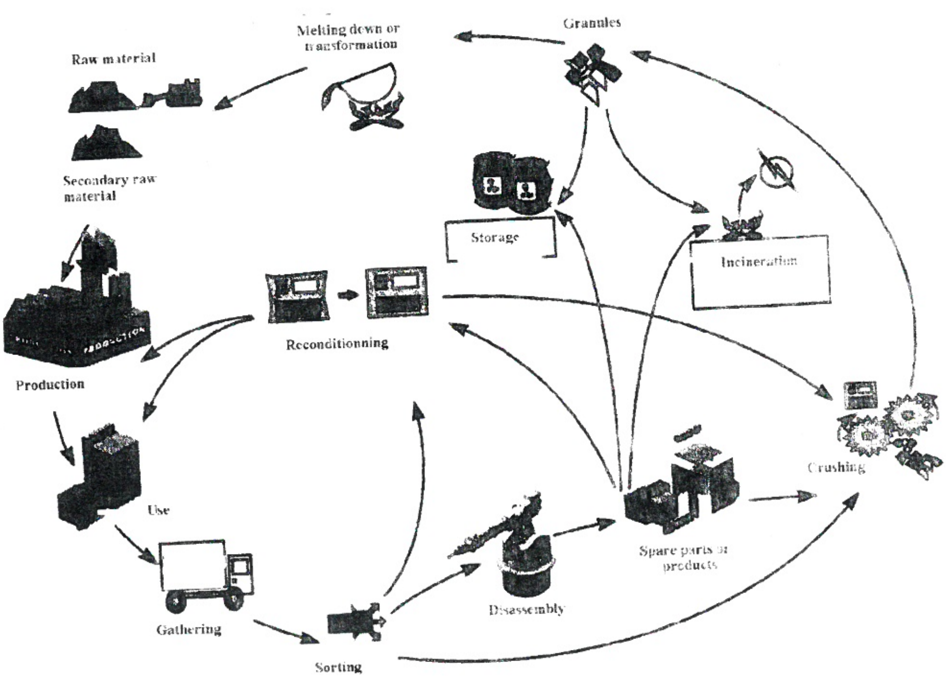

Figure 1: Product life-cycle

Disassembling is a non-destructive technique and implies the extraction of the desired components and/or materials. If the parts are not reusable after reconditioning, partial or total destructive operations are applied: drilling, cutting, wrenching, and shearing. These techniques are used with the view of material or energetical recovery.

In this context, disassembly is the main stage in the product end-of-life treatment.

The disassembly process with the view to recycling the manufactured goods is considered in the literature as a *friendly environment technology*. It is integrated in a more complex system – the disassembly system that contains the resources, robots, automates, human factor and different devices used by the disassembly process. Each unit of a disassembly system is a disassembly cell. Nowadays, researchers are trying to conceive a complete automatic cell.

3. Conceptual modeling of a disassembly process

We can study the behavior of a disassembly system by using models that are easy to be experimented by simulation. In the literature, the methods used for modeling a disassembly process are devised in two categories: some for sequencing operations and some for planning and control. Most of the methods are based on the theory of Petri Nets.

Petri Nets are a graphical and mathematical modeling technique originally developed to model computer system. They have been extended and applied to a wide variety of systems, including manufacturing ones. PNs are useful for modeling systems characterized as concurrent, asynchronous, distributed, parallel, and/or stochastic, in which operations share multiple resources. PN models can be analyzed to determine qualitative and quantitative proprieties of the system.

For example, in (Moore, 1998) the authors use the Disassembly Petri Net (DPN) to represent the sequences. DPN is in fact an AND/OR graph which take into account the precedence between the components.

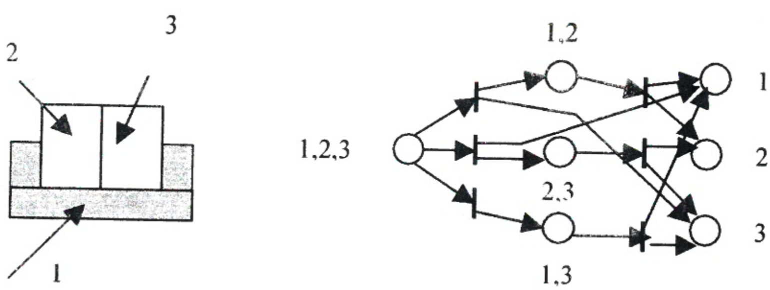

Figure 2: DPN

In (Zussman, 1999) is presented a DPN in case of a telephone handset. In this Petri net a place is regarded like a product, subassembly or part, and a transition correspond to a disassembly operation.

$$DPN = (P, T, I, O, m_0, \pi, \tau, \delta)$$

Where:

1) $Z = (P, T, I, O, m_0)$ is an acyclic Petri Net such that:

(a) There is a place called root denoted by p_I with no input arc, a set of places called subassemblies, a set of places called parts or leaves denoted by P', each of which has no output arcs
(b) Each transition has at most one input arc and at least two output arcs;
(c) The mark is initial in the root place, means:

$$m_0(p_1) = 1 \qquad m_0(p) = 0 \qquad \forall p \in P - \{p_1\}$$

(d) The terminal marking is on terminal places only if no transition is enabled.

2) $\pi : P \rightarrow R$ is a utility function assigned to a place where R is the set of real numbers.

3) $\tau : T \rightarrow R^+$ is a cost function assigned to a transition;

4) $\delta : T \rightarrow N$ is a decision value associated with a transition; it is determined via an internal planning algorithm;

5) $p : T \rightarrow [0,1]$ is a probability value associated with a transition and it is updated according to the corresponding operation performed by external resources; the value $p(t)$ represents the success rate of a disassembly operation while the value of $1 - p(t)$ represents the failure rate.

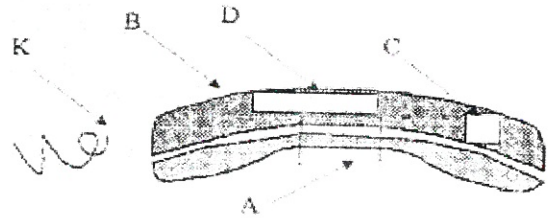

Figure 3: The components of a telephone handset

The handset is used as an example for modeling with DPN based on the given product specifications (Figure 3.). The handset consists of four parts, A, B made from thermoset plastic, part C made from steel and part D is a printed circuit board. In Figure 4. is represented the corresponding Disassembly Petri Net.

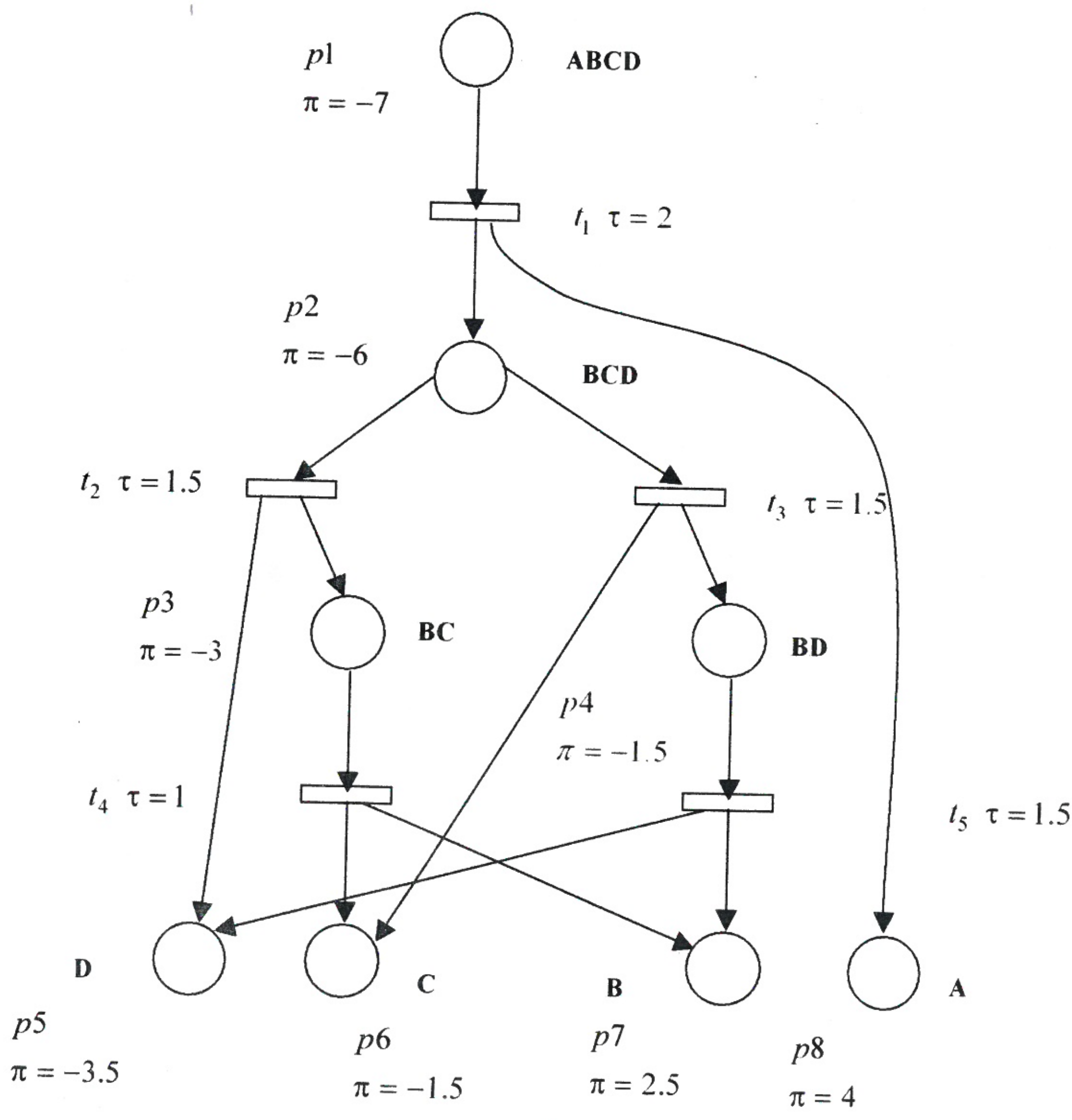

Figure 4: DPN

In order to represent a disassembly sequence T.C. Kuo (Kuo, 2000) uses a disassembly tree that associates for each branch the direction of the disassembly operation. The idea of using disassembly trees has the origin in that of assembly trees that where first presented in (Henrioud, 1989). Thus, the disassembly process is regarded as the reverse of the assembly. However, the success of disassembly operations can be affected by different characteristics of the components, by the uncertain product conditions after usage, deformations, material deficiency, etc.

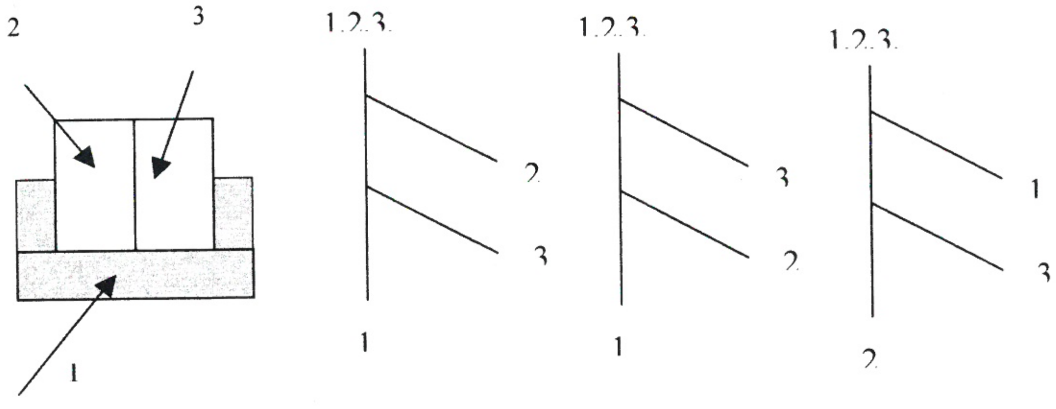

Figure 5: Disassembly trees

In (Penev, 1996) the disassembly process is represented by a reusing point of view of a target component. The authors use the theory of graphs and the method of dynamic programming for the generation of the disassembly plans. They propose a disassembly graph (Fig 6.). The discarded good to be disassembled is in initial state A. The nodes represent the states of the disassembly goods. This means that every state contains a collection of parts and sub-assemblies; for each state the collection of parts and sub-assemblies is unique.

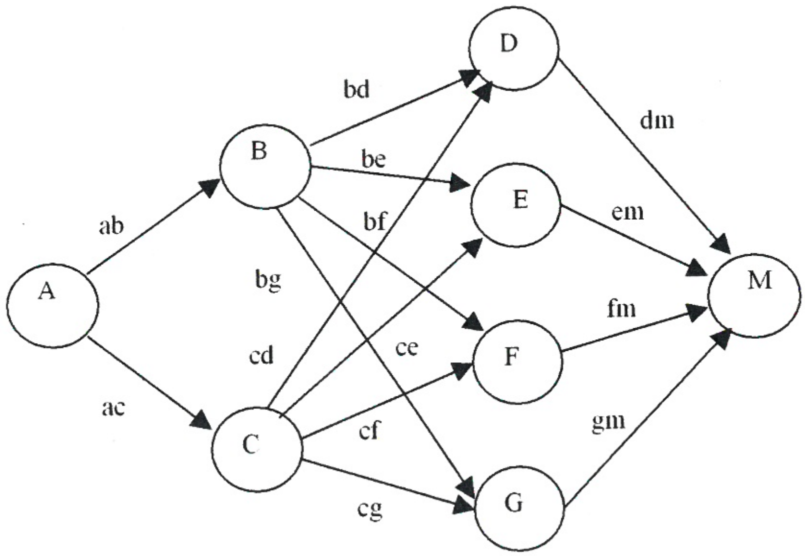

Figure 6: Disassembly graph

The state M obtained after a number of disassembly operations contain a desired part that has to be recovered. This means that the good has to be disassembled so that the desired part can be released.

4. Disassembly system control

There are few articles in the literature that treat control of the automatically disassembly, due to the natural reason that no automatic disassembly cell has been ever implemented. However, at the Institute WBK of Karlsruhe – Germany, it was realized a hybrid disassembly cellule in which activates a robot and a man.

The control of the disassembly system can refer to the production flow, balancing, disassembly line, or to the command of different resources.

In this context we are proposing a new method: object-modeling technique (OMT).

The object-oriented approach provides decomposition of the disassembly system in object with associated attributes and methods (operations). The product, subassemblies, automates, robots, disassembly line, can be objects and their main functions and characteristics can be attributes.

In recent years there has been considerable interest in applying object-oriented technique to Petri Nets. It is interesting to represent objects from a disassembly system using Object Oriented Petri nets (OOPN).

The definition of Object Petri nets derived from that of Coloured Petri Nets.

In an OOPN places are operations, the mark of a place is the state of the object, and transitions represent temporal or physical disassembly restrictions.

In Fig. 8 we represented an OOPN for an elementary production cell. In the place FM (free machine) we have the initial mark. Objects type "products" are in a waiting supply WS. Due to transition E a mark goes from WS and from FM to the place OM (occupied machine) that correspond to an executed operation. The transition "end of execution" (EE) is fired only if the precedent operation is the last one from the operational chain. Else, the transition "end of intermediary execution" (EIE) is fired. After the transition EE the product goes to the final supply (FS).

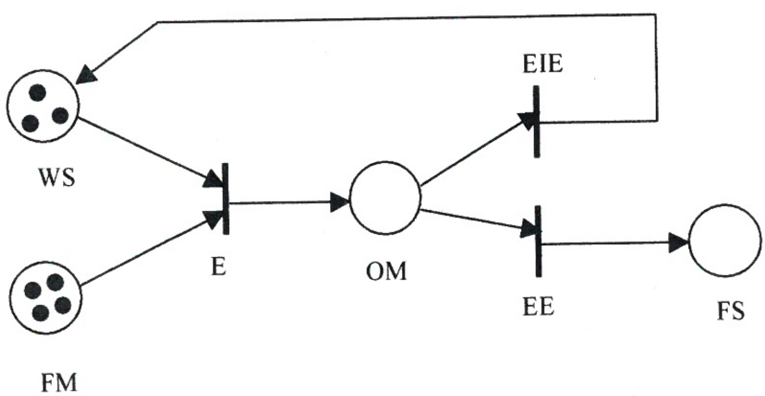

Figure 7: Example of a OOPN

Using this method we can represent the disassembly system as well as disassembly process with all its phases.

Now, assuming that we have to disassembly one component with an uncertain state after usage, we must consult the end-of-life options of the component: reusing, recycling, material or energy recovery. In the next figure P_1, P_2, P_3 are the places for the disassembly operations and places P_4, P_5 and P_6 can represent the end-of- life options.

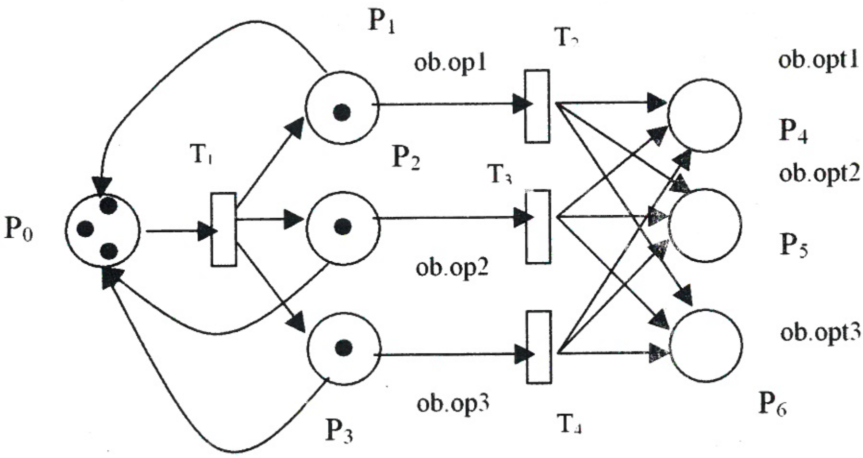

Figure 8: Disassembly OOPN

Object oriented paradigm has the advantage that allows the implementation of the system control using programming techniques and languages (for example C++ or Visual C++). Object Oriented Petri nets support encapsulation, inheritance, polymorphism and dynamic binding which are common in object oriented languages. In the same time is important to synchronize the actions of an object and its components with commands that take in account the states of these elements.

In the meantime, in a disassembly OOPN (DOOPN) we can dynamically create objects, each encapsulating its own data and control structures, together with the ability to generate new instances of such objects. This means that DOOPN support the dynamic interaction topologies, so they are suitable for modeling the system control.

A new language for Object Oriented Petri Nets was implemented in (Lakos, 1996) called LOOPN. LOOPN support two class hierarchies - one for token places and one for sub-nets. Inheritance, overriding and polymorphism for token types led to some interesting results in the modeling of layered network protocols, with one protocol layer being able to transfer any kind of message token.

Future work has to concentrate on the analysis and evaluation of the proposed object-oriented models and has to find a suitable tool for simulating the activity and the control of a disassembly system.

5. Conclusions

For the last several years, recycling technologies have been continuously improving. However, in order to recycle products in an efficient way, a systematic process such as disassembly allows reusable, non-recyclable, as well as hazardous components to be selectively separated from recyclable ones. This article is a short review of some modeling methods for disassembly systems and a modest attempt to present a new method: object-modeling technique using Petri Nets.

REFERENCES

1. CHEVRON D. (1999), **Contribution à l'étude de la supervision d'une cellule de démontage de produits techniques en fin de vie**, Thèse de doctorat, Institut National Polytechnique de Grenoble, 10 Nov. 1999.

2. FILIP, F. G., B. BARBAT (1999). **Industrial Informatics; New Paradigms and Applications.** Technical Publishers. Bucharest (In Romanian).

3. GERNER S. (2001), **Génération d'un processus de désassemblage et évaluation du recyclage d'un produit**, Thèse de doctorat, Institut National Polytechnique de Grenoble, sept. 2001

4. HENRIOUD J.M, (1989), **Contribution à la conceptualisation de l'assemblage automatisé : nouvelle approche en vue de la détermination des processus d'assemblage**, Thèse de doctorat, Université de Franche Comté, France, 1989

5. KUO T.C., ZHANG H.C., HUANG S.H. (2000), **Disassembly analysis for electromechanical products: a graph based heuristic approach**, International Journal of Production research, vol. 38, no.5, 2000

6. C.A. LAKOS (1995), **From Coloured Petri Nets to Object Petri Nets**, Spring Veerlag, Vol. 935, 1995

7. C. A. LAKOS, C. KEEN (1996), **LOOPN++: a new Language for Object-Oriented Petri Nets**, Proceedings of Modeling and Simulation, Barcelona, 1996

8. MOORE K., GUNGOR A., GUPTA S. (1998), **Disassembly process planning using Petri Nets**, Proceedings of the IEEE International Symposium On Electronics and Environment, Oak Brook, Illinois, USA, 1998

9. PENEV K.D., DE RON A. J., (1996), **Determination of a disassembly strategy**, International Journal of Production and Research, vol. 34, no. 2, 1996.