

An Object-Oriented Approach to Curriculum Design

Valery Vodovozov and Zoja Raud

Department of Electrical Drives and Power Electronics, Tallinn University of Technology
Tallinn, 19086, Estonia

ABSTRACT

An object-oriented model of a learning system is proposed to optimize the methodical resources of higher educational institutions, particularly their curricula, syllabi, schedules, studies, etc. Unlike the procedural approach, an object-oriented paradigm divides the system into the classes of interactive objects. The hierarchical system of the classes *Thesaurus*, *Studies*, *Disciplines*, and *Concepts* underlay the model. The proposed approach contributes into the education development and improving. It helps to prepare the basic modules for particular teaching methods, to emphasize the disciplines without doubling, and to realize the procedure inheritance in the educational institutions.

Keywords: Educational system, Object-oriented model, Teaching methods, Curriculum, Thesaurus.

1. INTRODUCTION

To plan an educational process, the procedural approach is used traditionally. It is based on an algorithmic decomposition of the solved problem by the consecutive determining of evident formalized tasks [1],[2]. Each problem is fitted by its own *procedure*, which describes the actions upon the objects. Such «share and rule» decomposition assumes the problem breaking up into the set of tasks solving of which leads to the solution of the whole problem. Thanks to the logical segmentation, a lot of planning, management, and documenting processes are arranged effectively [3].

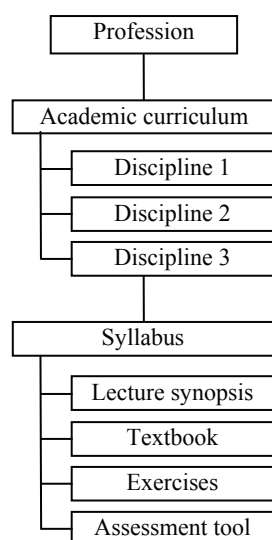


Fig. 1. Functional decomposition diagram

The algorithmic procedural approach serves as the first stage of a top-down design. As an algorithm is the rule set that appoints the final sequence of the time-determining actions, the procedural decomposition may be represented by a decision tree an example of which is given in Fig. 1. This diagram of a learning process includes the root, branches, nodes, and leaves. The leaves exhibit the particular learning instruments whereas the nodes involve the normative documents and the branches display their connections. The drooping from the root to a leaf along some trajectory is a technique to solve the majority of the problems in educational planning.

To arrange an educational process using the procedural approach, a designer has to understand fully the contents of the whole system, its structure, the principle of operation and behaviour [4]. In a word, the problem is to be analysed carefully before the solving. While the algorithm is not built, it is impossible to start the document development and execution otherwise the system does not fit the design requirements [5], [6]. Violation of this rule complicates the planning of the teaching activity and often arouses errors.

The goal of this work is to build the model suitable for planning the optimal educational trajectories.

2. OBJECT DECOMPOSITION OF AN EDUCATIONAL SYSTEM

To analyze and evaluate the procedural model, pick out the main objects of an educational system. Assume a *Concept* is an elementary object of the model. Any concept is the unit of knowledge created by a unique combination of characteristics. It describes the objects by the sets of the common and specific named professional signs. The academic process is devoted to form the skills and ideas through the concepts thus providing the solving of the professional problems within the broadest area.

The course of a specialist training in an educational institution is described by an *Academic curriculum* procedure. To analyze the possible approaches to the training planning, use the curriculum as the most common model of the profession mastered by a student (Fig. 2).

Consolidate the set of the professional concepts into the object called *Thesaurus*. Besides the concepts, all the *Disciplines* and *Studies* are the members of the thesaurus. They are considered as the objects of the discussed educational model as well.

The professional concepts are defined within the particular disciplines of the curriculum. A discipline plays the role of the teacher and learner source of ideas about the particular knowledge domain. Let the *Syllabus* procedure that describes an

educational structure and interaction be a model of the particular discipline where the professional concepts are distributed among the different studies. It may well be so that the concepts, which are similar in names but different in contents be repeated in the thesaurus.

In turn, let a *Study* procedure be the model of an elementary educational process that defines a concept. The concept content exposes through a dozen of other preliminary described concepts as well as through the standard terms, which are the elementary knowledge units indivisible on the discussed simulation level. The theoretical and practical studies are distinguished traditionally. Particularly, a lecture serves as the model of the theoretical (logical, mathematical, pragmatic, or philosophic) concept conclusion, a laboratory practicum provides the experimental deduction of some concept through other one, a course work is a model of the self-dependent generation of the new concepts whereas a seminar represents the common knowledge and skill outcome system.

The studies description is taken away the discussed system outline. It is performed by a teacher in the real educational process where he forms the student knowledge, skill, and ideas about the subject of study.

Note that the thesaurus is a very dynamic system renewed along with the professional level development. The new concepts, disciplines, and studies enrich thesaurus whereas the existing definitions are subjected to clarifying and obsolete ones are deleted. In contrast to the informational and technical systems, the educational thesaurus is based on the only concepts, which are in active use in professional activity being defined earlier through other educational concepts.

At the same time, it is important to take into account that the conceptual apparatus of an educational system should be changed regularly along with the studies. In learning, an elementary concept is introduced firstly, which is specified, enlarged, and filled with examples and exceptions. As a result, the particular studies stipulated by the syllabus help the student to build its own conceptual system thus approaching the system required by the curriculum. An efficiency of one or another educational environment is defined by the mastering speed developed by the learner as well as by his knowledge completeness.

From the proposed object model view, the above-discussed procedural approach has a number of disadvantages. First, it arouses the intersections of the learning processes because of the lack of protection from the concept repetition in different disciplines and studies. Following a crossing, a number of links and the length of the educational trajectory increase. Moreover, any alteration of a process data calls an edition of other processes. Thus, the data change may provoke violation in the study course. To avoid doubling, the curriculum writers try to involve the concepts defined in other disciplines. Often, such «task selectivity» leads to the violation of the informational perception due to the mixing of the task order.

It becomes very difficult to describe the complex systems using the «pure» procedural technique. The reason lies in the nature of a modelled object because any procedural model suspects a one-sided, incomplete, and prejudiced glance on the original. In reality, this glance alters with the designer's experience and

professionalism improvement. Above all, an object itself is in progress gradually thus inciting to evolve the model adequately.

3. OBJECT-ORIENTED APPROACH

An object-oriented approach is effective perennially when the desired system has the mutual correlation of different components and continual variation of connections. Its application in planning and scheduling is discussed in [7]. The particular researches were devoted to the implementation of this approach into education [8],[9].

Unlike the «pure» procedural approach that describes a system by the actions upon objects and phenomena, the object-oriented paradigm is based on the classes of interacted objects. A *class* is the generalized model of the group of similar objects, which characteristics are presented by the properties and which behaviour is described by the procedural patterns without concrete values [10]. The class properties and procedures are called *members*. Each system object is a representative of a class. The object characteristics and behaviour do not depend on other classes therefore it is not required to know other classes to understand the particular class logic. An association of the property and behaviour description in the class is the main distinction of the object-oriented approach from the procedural method where the properties are separated from the executed procedures.

A class is constructed by an *encapsulation* technique, which provides the member selection and fixes their accessibility outline in relation to the external model components. Such visibility restriction conceals the details, which have no importance for the objects of other classes. As a result, an object is considered as an entire unit, which realization is hid from external interferences. For that, at least two groups of members are marked out in a class. The private member group describes the tools for the class implementation whereas the public members serve as an interface of the private members with the outer objects. In addition to the usual classes, the abstract classes exist, which members play a role of the patterns to build other classes. These classes have no objects.

Next peculiarity of the object-oriented approach called *polymorphism* touches the giving of the identical names to the procedures that solve the similar problems by different ways. Polymorphism adapts the logic of the model functioning to the object specifics and simplifies understanding of the object behaviour. It serves as a tool of different implementations of the procedures having the same names dependently on their position in the object hierarchy. This technique acts beneficially on the system expanding and improving. Following by [10] to reflect the described essence, the polymorphous objects are often designated by nouns, the classes – by generalized nouns, and the procedures – by verbs.

The third feature of the object-oriented approach is known as *inheritance*. It establishes the conditions to build the new classes without repetition of the early prepared descriptions. Inheritance serves as an instrument of the application of the earlier defined generic classes to build the derived classes by reuse and edition their public members. This technique promotes avoiding the doubling, increasing reliability, and improving the model representation. Inheritance results in the uniform class interface where any variation of the generic class

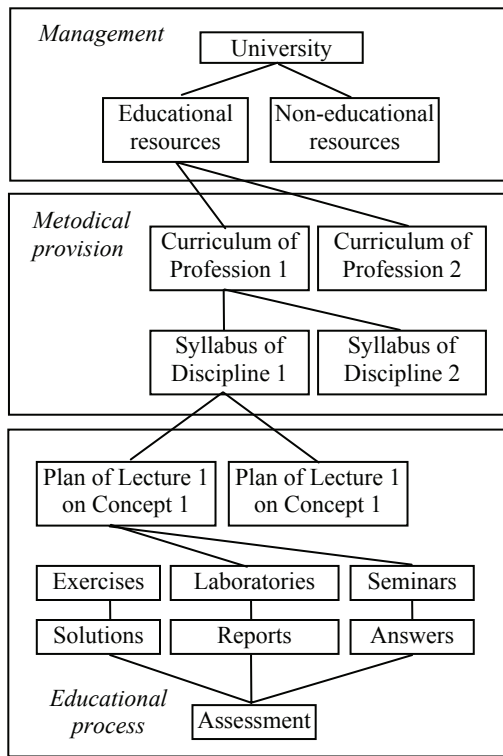


Fig. 2. Object decomposition of educational process

calls automatic change of the derived class as well as any error in the generic class is fixed by all hierarchical levels.

4. CLASS-BUILT MODEL OF EDUCATIONAL SYSTEM

The objects and procedures of the model shown in Fig. 2 were connected in space (Fig. 3) and in time (Fig. 4). As a result, the class ensemble was built shown in Fig. 5. The proposed object-oriented educational model is an instrument to generate a professional thesaurus which guaranties the shortest educational trajectory.

The *Thesaurus* plays the role of an abstract generic class of the observed model. The members of the class are as follows: the public property *Name* which identifies the objects and the abstract procedures *Get()* which serves to obtain the required object data, *Find()* to search an object, *Put()* to place an object into the thesaurus, and *Del()* to delete an object from the thesaurus.

The *Studies* is the derived class descended from *Thesaurus*. It generates such objects as lectures, exercises, seminars, end so forth that inherit the property *Name* of the generic class *Thesaurus*. The study object behaviour is characterized by the open procedures *Get(Name)* to obtain a name of the study, *Find(Name)* to search a name in the thesaurus, *Put(Name)* to place a name into the thesaurus, and *Del(Name)* to delete a name from the thesaurus.

In turn, the class *Disciplines* comes from *Studies*. It inherits the property *Name* and involves an additional property *i*, which designates the starting time of the concept definition. Traditionally, the time is measured by the academic weeks though other, more flexible units may be used instead. In

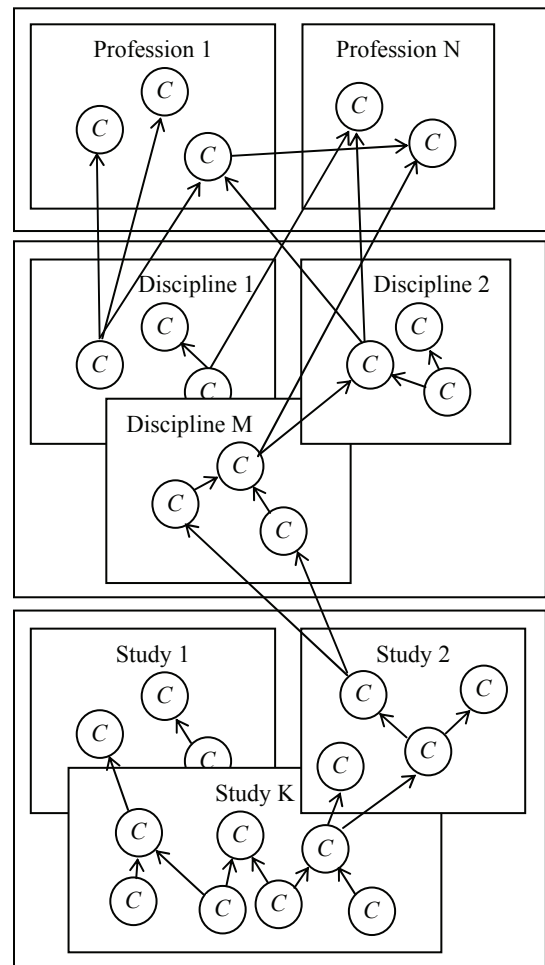


Fig. 3. Object interaction of professions

addition to the inherited procedures *Find(Name)* and *Del(Name)*, the objects of the class *Disciplines* operate with the public procedures *Get(i, Name)* to obtain a name and time of a discipline, and *Put(i, Name)* to place a discipline into the thesaurus.

Finally, the derived class *Concepts* is formed from *Disciplines*. In addition to the inherited properties *Name* and *i*, its objects have the private properties *Dis* – a discipline which defines a concept, $S_1...S_k$ – the studies devoted to a concept, and $C_1...C_p$ – the preceding concepts that define the current one. The behaviour of a concept is described by the renewed procedures. The procedure *Get(i, Name, Dis, S₁...S_k, C₁...C_p)* acquires the name, the discipline, the studies, and the defining concepts of a new object. The procedure *Find(i, Name, S₁...S_k, C₁...C_p)* searches a concept in the thesaurus whereas *Put(i, Name, Dis, S₁...S_k, C₁...C_p)* puts it into the thesaurus along with *i* calculation, and *Del(i, Name)* erases a useless concept.

A thesaurus is produced as follows.

First, the objects of the class *Studies* are constructed. They are entered by the procedure *Get*. The system seeks for each new study in the thesaurus using the procedure *Find* and then puts the absentees into the thesaurus by the procedure *Put* indicating the required time position.

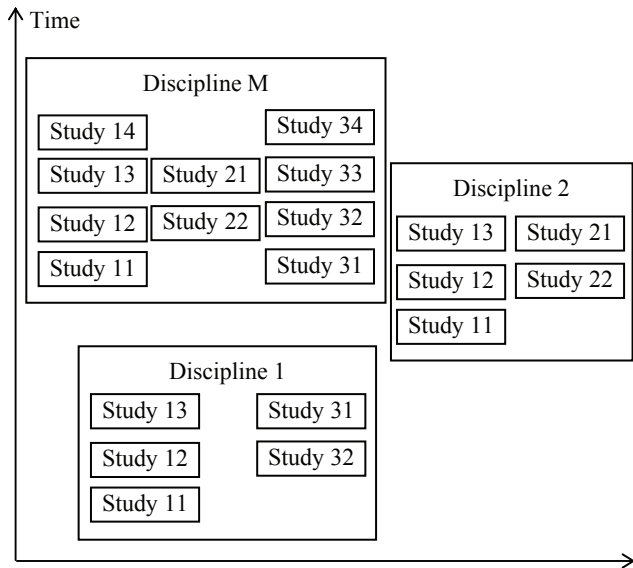


Fig. 4. Object sequence of a profession

By analogy, the objects of the class *Disciplines* are generated. The absentees are accommodated into the thesaurus by the procedure *Put*. If the procedure *Find* returns the searched discipline with i differed from the value given in *Get*, the procedure *Put* corrects the time.

Then, the thesaurus is filled by the concepts. The procedure *Get* introduces each new concept. The procedure *Find* searches for the concept name in the thesaurus and returns the properties $i, S_1...S_k, C_1...C_p$ of the object detected. Next, this result is used by the procedure *Put*, which compares the received values of $S_1...S_k$ and $C_1...C_p$ with the values given by the procedure *Get*.

If the concept is not defined yet, the procedure *Put* adds it into the thesaurus with the lowest timing position i .

On the other hand, the concept may be detected in the thesaurus as incomplete object without some studies given in the list $S_1...S_k$ or without some concepts given in the list $C_1...C_p$. In this case, the procedure *Put* enters the concept into the thesaurus again and indicates the value i obtained from the detected concept. In addition, the missing values of the properties $S_1...S_k$ and $C_1...C_p$ are placed into the renewed concept. To calculate the time i , the procedure *Find* searches the values i of all defining concepts given by the list $C_1...C_p$. The greatest of the values $i = i_{max}$ represents the seeking value $i > i_{max}$ of the renewed concept.

Unnecessary objects are erased by the procedure *Del*.

In this way, the proposed model protects the thesaurus from the doubling of the concepts, disciplines, and studies. It defines automatically the succession of the concept definition in an educational process.

5. CASE STUDY OF THE THESAURUS IN ELECTRONICS

The total capacity of the concepts used by electronics specialists in their professional activity is enough great. Its volume may be calculated by means of different methods. Particularly, Electropedia (also known as the IEV Online System) is the world's most comprehensive online electrical and electronic terminology database containing more than 20 000 terms and definitions [11]. Electropedia is produced by the IEC, the world leading organization that prepares and publishes international standards for all electrical, electronic and related technologies collectively known as electrotechnology. Electropedia contains all the terms and definitions in the International Electrotechnical Vocabulary or IEV, which is presented also as a set of publications in the IEC 60050 series that can be ordered separately from the IEC webstore.

Assume a fragment of the professional thesaurus supported by the course AAR3320 – Electronics and semiconductors includes some concepts like these:

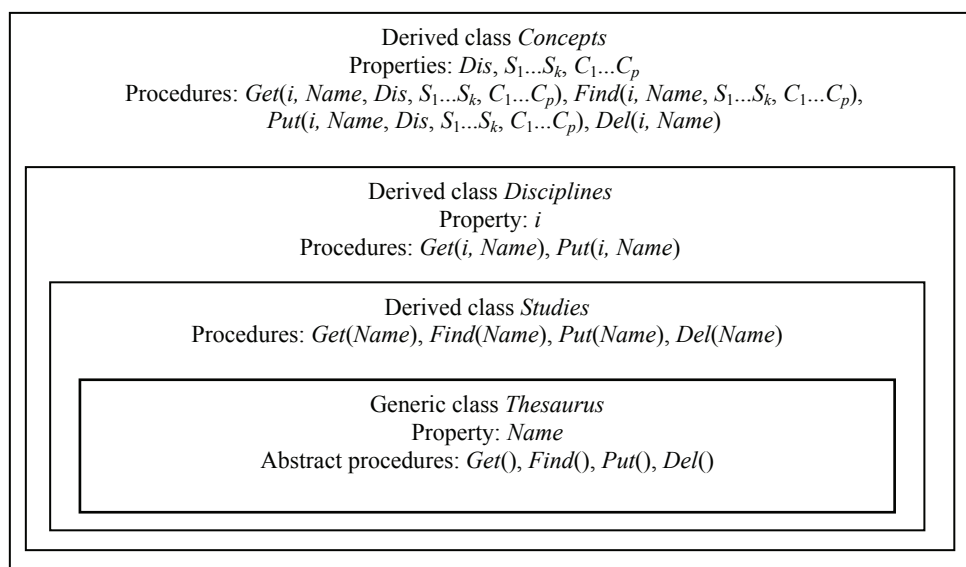


Fig. 5. Class-built model of a professional educational system

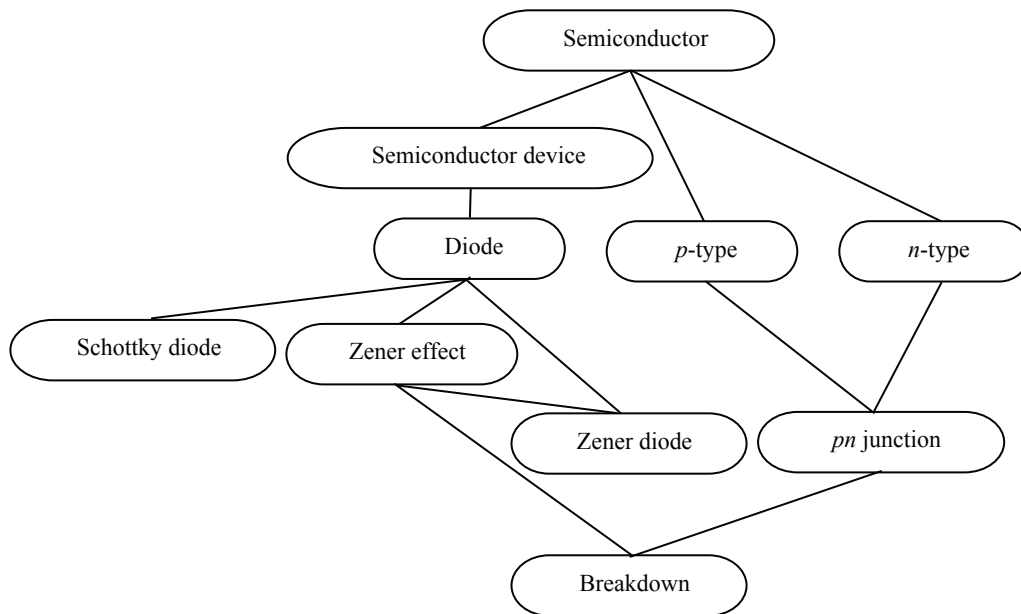


Fig. 6. Fragment of a concept tree

1. **breakdown** - reverse *voltage* of a **pn junction** where the **Zener effect** occurs
2. **diode** - two-terminal **semiconductor device** serving as a *conductor* being *forward biased* and as an *insulator* being *reverse biased*
3. **pn junction** - area between **p-type** and **n-type layers**
4. **Schottky diode** - high-*frequency diode* with no *depletion layer*
5. **semiconductor** - element that may serve as a *conductor* being *forward biased* and as an *insulator* being *reverse biased*
6. **Zener diode** - **diode** designed to operate in the **Zener effect** area
7. **Zener effect** - effect of high *current* occurring under certain *reverse voltage*
8. **p-type** - *trivalent impurity* of a **semiconductor**
9. **n-type** - *pentavalent impurity* of a **semiconductor**
10. **tunnel diode** - *heavily doped diode* with a zero **breakdown**
11. **semiconductor device** - *electronic device* built on **semiconductors**

Here, the concepts are given by the bold types, and italic font is used for the terms. The specific concepts occupy the left side of each definition whereas the component concepts are to the right.

Figure 6 gives a fragment of the thesaurus as a concept tree, which concerns some concepts introduced in the course. Using such bottom-up structure, the students and teachers can capture the concepts and evaluate learning.

To support the basic concepts of the application area and to reflect the modern challenges being an instrument for solving the practical problems, a thesaurus should possess enough redundancy. Really, different professional branches of knowledge require the sets of specific concepts thus an excess capacity of concepts and disciplines is the normal feature of any thesaurus. Particularly, in the course AAR3320 the known

examples of such branches are Industrial electronics, Medicine electronics, Domestic electronics, Automotive electronics, On-board electronics, end so forth. As the total number of professional concepts is much greater than a number of concepts a student should accept within the learning period, the personal educational trajectories may differ dependently on the students' goals and the future degree that a learner approaches. To prepare the graduates for different application areas, the specific educational trajectories are needed thus some groups of concepts and particular disciplines of the full thesaurus are to be avoided in a way that the overall required volume of credit points be preserved during the curriculum development.

Therefore, the proposed system of the consolidated disciplines aggregated into a curriculum is an enormously suitable tool to generate the particular educational trajectories. Being connected by means of concepts, the disciplines successfully support a total plan for learning. In Fig. 7, the avoided concepts are given by the dotted lines whereas the solid nodes and branches indicate the particular educational trajectory.

6. CONCLUSION

The structure of an educational system and its component composition has been discussed. The problem functional and object analyses were carried out. Using the object decomposition, the object and the class models were developed and the possible object elaboration was looked over. The proposed object-oriented approach contributes into:

- design, development, and improving of educational resources
- development the basic modules for particular teaching methods of different disciplines
- choosing the disciplines, studies and concepts in the learning modules without doubling
- procedure inheritance in academic development and renovation.

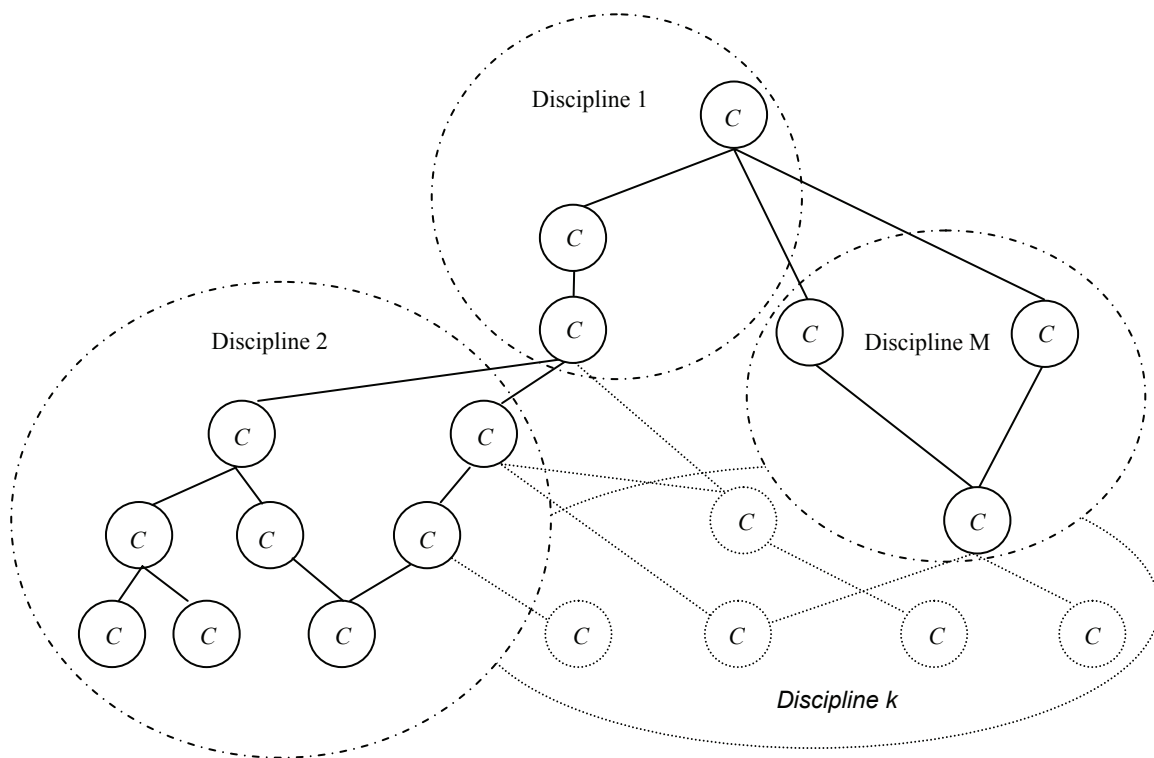


Fig. 7. Concept aggregating into the disciplines

ACKNOWLEDGEMENT

This paper is supported by Estonian Science Foundation Grant ETF8020.

REFERENCES

- [1] M. McCredie and R.E. Rice, "Trends in analyzing access to information", **Information Processing and Management**, Vol. 35, 1, 1998, pp 45-99.
- [2] G. Andaloro and L. Bellomonte, "Student knowledge and learning skill modelling in the learning environment forces", **Computers and Education**, Vol. 30/3-4, 1998, pp. 209-217.
- [3] N. Wirth, **Algorithms + Data Structures = Programs**, NY:, Prentice Hall, 1976. 400 p.
- [4] J. Liebowitz, "The role of knowledge-based systems in serving as the integrative mechanism across disciplines", **Learning and Instruction**, Vol. 9, 1998, pp. 559-564.
- [5] K. Ishino, K. Sugai, and R. Mizoguchi, "An intelligent educational system which supports scientific thinking", **IV Pacific Int. Conf. on AI**, Australia, 1996.
- [6] M.M. Reis, E.P. Paladini, S. Khator, and W.A. Sommer, "Artificial intelligence approach to support statistical quality control teaching", **Computers & Education**, 47, 4, 2006, p.448-464.
- [7] M.A. Badri, D.L. Davis, D.F. Davis, and J. Hollingsworth, "A multi-objective course-scheduling model: combining faculty preferences for courses and times", **Computers and Operation Research**, Vol. 25, 4, 1998, pp. 303-316.
- [8] V.A. Dubenetsky, B.Y. Sovetov, and E.V. Rastokina, "Object-oriented technology of study and research the subject areas", **5th International Conference "Contemporary educational technologies"**, St. Petersburg, 1999, p. 70-71.
- [9] S. Xinogalos, M. Satratzemi, and V. Dagdilelis, An introduction to object-oriented programming with a didactic microworld, **Computers & Education**, Vol. 47, 2, 2006, pp 148-171.
- [10] G. Booch, **Object Oriented Analysis and Design with Applications**, Addison-Wesley, 1993, 608 p.
- [11] **Electropedia: The World's online electrotechnical vocabulary**, Available at: <http://www.electropedia.org/>