Journal of Machine Engineering, Vol. 12, No. 1, 2012

engineering ontology, basic geometrical primitives, cmm, protégé

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TOWARDS THE DEVELOPMENT OF FEATURE – BASED ONTOLOGY FOR INSPECTION PLANING SYSTEM ON CMM

The paper define the basic geometrical primitives as classes of Engineering Ontology in order to develop feature – based ontology for Inspection Planning System for CMM. The process of acquisition the properties of individuals and properties of classes is proposed, as one of the main components of Engineering Ontology, suitable for implementation in the software for development the ontology – Protégé. The proposed method describes derived geometrical characteristics or characteristics that are measured on the mechanical part. The results indicate that further development of methodology for Engineering Ontology is justified in the field of production metrology and implementation in the appropriate software.

1 INTRODUCTION

The inspection of the mechanical parts with many different types of tolerance mainly performed on the CMM. The CMM is the key tools of the inspection in industry, and they make the area of Computer-Aided Inspection (CAI) technology. The CAI system requires the information about part that should to be measured, and the CAD system has it. A bridge between the CAD and the CAI is the Computer-Aided Inspection Planning (CAIP). The CAIP is the critical link between CAD and CAI [1]. One of the key problems today is integration CAD / CAI.

In [1] is given a feature-based CAI for CMM and only the mechanical parts that consist from the feature, it is described with seven variables parameters. For a set of mechanical parts those can be described using a defined features it is possible to automatically generate the inspection plan. However, with defined features can't be define sphere, torus, cone and ellipse.

Knowledge – based engineering give the different ways of implementation an Inspection Planning Activity [3],[4], but not enough to overcome the gap between CAD and CAI. CAD/CAPP integration [5], using feature ontology can serve as an example of the application the Engineering Ontology (EO) in solving the mentioned problems. In order to

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establish integration, it is necessary to define the ontology [6], through defining its basic components (classes, individuals and properties) using the method given in [7]. The solution of problem integration can be based on STEP [8].

Table 1. The geometrical primitives and their parametars [2]

Mark	Characteristics	Parameters		
		Coordinates X_0 Y_0 Z_0	Normal vector E_x E_y E_z	Parameters D D_1 D_2 W
*GP1	Point	+ + +		
GP2	Line	+ + +	+ + +	
GP3	Circle	+ + +	+ + +	+
GP4	Ellipse	+ + +	+ + +	+ +
GP5	Plane	+ + +	+ + +	
GP6	Sphere	+ + +		+
GP7	Cylinder	+ + +	+ + +	+
GP8	Cone	+ + +	+ + +	+
GP9	Torus	+ + +	+ + +	+ +

*GP – The Geometrical Primitives

Table 2. The derived geometric characteristics

Mark	Characteristics	Nominal value
*GC1	The distance between two points	+
GC2	The distance between two spheres	+
GC3	The distance between point and line	+
GC4	The distance between sphere and cylinder	+
GC5	The distance between point and plane	+
GC6	The distance between sphere and plane	+
GC7	The angle between lines in the plane	+
GC8	The angle between lines in the space	+
GC9	The angle between line and plane	+

*GC – The Geometrical Characteristics

In engineering the term of ontology is primarily related for knowledge representation. Authors such as *Swartout, W.R. & Tate*, A. associated the ontology with the base of knowledge, arguing that it is represent the basic logical structure around which to build a knowledge base. The development of Intelligent Systems for Inspection on CMM requires the development of a knowledge base. Development of the knowledge base precedes the formal specification of domain, which must start from the basic geometric features (e.g. point, line, spheres, etc.). Combine basic geometric features we obtain complex geometric features and derived metrological characteristics (e.g. distance between two holes, the distance between two planes, etc.). Obtained metrology description is a formal presentation of necessary relations between classes and / or individuals.

The method presented in this paper, represent the attempt to exploit some of the basic properties of ontology engineering, such as classification, reusability and logical structure around which to build a knowledge base for intelligent inspection planning system for the CMM. In this paper is proposed ontological description of geometrical primitives (point,

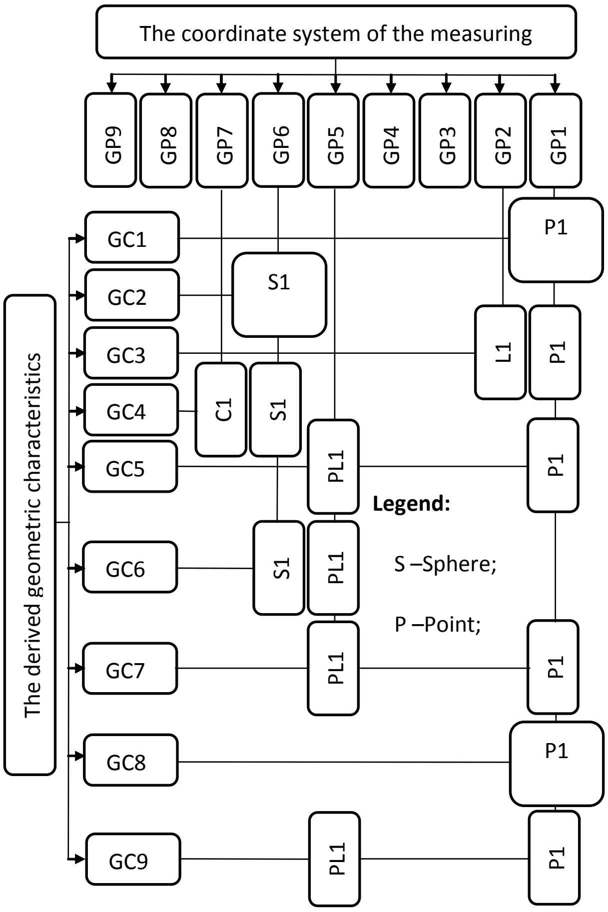

Fig. 1. The principle of description geometrical primitives and derived geometrical characteristics - based of the feature

line, circle, ellipse, plane, sphere, cylinder, cone, and torus) in order to get all metrological information needed for process control and inspection mechanical parts. In order to perform the process of inspections all the information has to be given about ideal geometry. Ideal geometry from the aspect production metrology is defined by the CAD model of the measuring parts and it is described the basic geometrical primitives, which are determined by the parameters given in Table 1. Derived geometrical characteristics are obtained by composing of the basic geometrical primitives (Fig. 1.). Each derived geometrically characteristics is specified by the nominal value (Table 2).

Description the dimensional tolerances and geometrical tolerances (form, orientation and location) are performing across of basic geometrical primitives. Geometric grounds on which are based softwares for CMM are basic geometrical primitives, which are detail discussed in [9]. The essence of the metrology software is an interpretation of geometrical primitives in a form suitable for their identification. This analysis starts from the point identification the derived geometrical characteristics, on basic ontological description of the geometrical primitives (Fig. 1.) on example of a mechanical part.

The justification of application the concepts of EO in the coordinate metrology are: (1) A unique and simple hierarchy of classes for each part, (2) Suitability for object-oriented programming (each individual is determined with accurately certain parameters), and (3) Links between geometric features and derived geometric characteristics fully describe by the method defined properties of the EO.

2. THE METHOD FOR ONTOLOGICAL MODELING THE GEOMETRICAL PRIMITIVES

The ideal geometry of the metrological model, for the purposes of generating inspection plan, is obtained by using basic metrology primitives, which are determined by appropriate parameters (Table 1.). These parameters uniquely determine every geometrical primitive in regard to the coordinate system of the measuring part. This set of parameters presents a set of metrological information about ideal geometry in the coordinate system of the measuring part, on the one hand and on the other hand some of these parameters are used for description of the derived geometric characteristics of the measuring parts (e.g. the distance between two holes).

Model information about the ideal geometry based on the ontological approach, presented in this paper, can be divided into:

- Set of metrological information about the ideal geometry in relation to the coordinate system of measurement (coordinate system of measuring part),
- Set of metrological information about the derived geometric characteristics of the measuring parts (a set of information about the relations between of the coordinate system task and coordinate system measuring part).

An approach for modeling the metrology information, as stated, is presented in [3], while others in [8]. The first concerns the integration of inspection activity while others on the integrated design and manufacturing based on STEP. The main difference of this model in relation to the previously mentioned of models is that this model is based on: (1) of defining geometric primitives as class of EO, (2) defining the relations between geometrical primitives as EO properties, (3) unambiguously define any primitives as individual given class .

Starting from the assumption that the basic geometrical primitives can be represented as a class engineering ontology, on the example of metrological model (Fig. 2.) that contains all the basic geometrical primitives, represented is its description from aspect of the EO.

2.1. SET OF METROLOGICAL INFORMATION ABOUT THE IDEAL GEOMETRY IN RELATION TO THE COORDINATE SYSTEM OF MEASUREMENT

In order to get a set of metrological information about the ideal geometry in relation to the coordinate system of measuring part, based on EO, we have to define what are the classes, individuals and properties (Table 3). Classes, individuals and properties are the main components of the EO and as such are detail described in [10].

From Table 3 can be seen that point as the basic geometrical primitive participate in the creation of other primitive, wich resulting in the existence of subclasses that correspond to other metrology primitives. Also, the table shows that in describing the geometrical primitives such as Line, Circle, Ellipse, Cylinder, Cone and Torus. Parameters given in Table 3 represent properties of the individual and in developing the information model they can be loaded as an input data.

By proposed method are covered all the basic geometrical primitives, so in accordance with those, measuring part (Fig. 2.) contains all the basic geometrical primitives. The proposed hierarchy of classes based on the choosing of geometrical primitives is the same for each the metrology part, except that will change individual number depending on the complexity of metrology part.

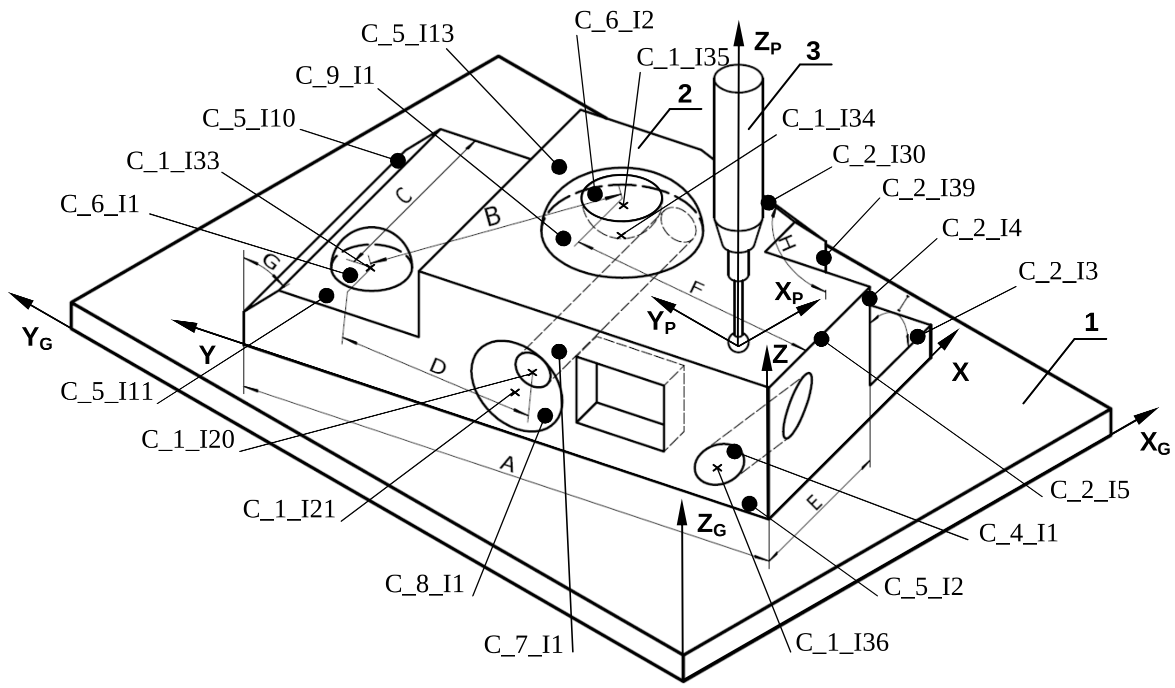

Fig. 2. The representation geometrical primitives as an individuals EO

Table 3. The representation of classes, individuals (i=1,2,3,...,n) and parameters for the ideal geometry in relation to the coordinate system of measurement [11]

Classes	Mark	Individuals	Parameters			n	Subclass e C_1	Subclasse C_5
			Coordinates X_0 Y_0 Z_0	Normal vector E_X E_Y E_Z	Parameters D D_1 D_2 W			
Point	C_1	C_1_I_i	X_{1i} Y_{1i} Z_{1i}			37		
Line	C_2	C_2_I_i	X_{2i} Y_{2i} Z_{2i}	E_{2Xi} E_{2Yi} E_{2Zi}		44	C_12	C_52
Circle	C_3	C_3_I_i	X_{3i} Y_{3i} Z_{3i}	E_{3Xi} E_{3Yi} E_{3Zi}	D_{1i}	6	C_13	C_53
Ellipse	C_4	C_4_I_i	X_{4i} Y_{4i} Z_{4i}	E_{4Xi} E_{4Yi} E_{4Zi}	D_{41i} D_{42i}	2	C_14	C_54
Plane	C_5	C_5_I_i	X_{5i} Y_{5i} Z_{5i}	E_{5Xi} E_{5Yi} E_{5Zi}		17	C_15	
Sphere	C_6	C_6_I_i	X_{6i} Y_{6i} Z_{6i}		D_{6i}	2	C_16	
Cylinder	C_7	C_7_I_i	X_{7i} Y_{7i} Z_{7i}	E_{7Xi} E_{7Yi} E_{7Zi}	D_{7i}	2	C_17	C_57
Cone	C_8	C_8_I_i	X_{8i} Y_{8i} Z_{8i}	E_{8Xi} E_{8Yi} E_{8Zi}	W_{8i}	1	C_18	C_58
Torus	C_9	C_9_I_i	X_{9i} Y_{9i} Z_{9i}	E_{9Xi} E_{9Yi} E_{9Zi}	D_{91i} D_{92i}	1	C_19	C_59

2.2 SET OF INFORMATION ABOUT THE RELATIONS BETWEEN OF THE COORDINATE SYSTEM TASK AND COORDINATE SYSTEM MEASURING PART

Table 4. The representation of classes, individuals and parameters for the derived geometric characteristics of the measuring parts

Classes	Marks	Individuals	Parameters			n	Subclasses K_1	Subclasses K_5
			Coordinates X_0 Y_0 Z_0	Normal vector E_X E_Y E_Z	Parameters D D_1 D_2 W			
The distance between two points (A)	C_21	C_1_I_i, i=2n	X_{1i} Y_{1i} Z_{1i} i=2n			1		
The distance between two spheres (B)	C_22	C_6_I_i, i=2n			D_{6i} i=2n	1	C_16_I_i, i=2n	
The distance between point and line (C)	C_23	C_1_I_i; C_2_I_i, i=n	X_{1i} Y_{1i} Z_{1i} i=n	E_{2Xi} E_{2Yi} E_{2Zi} i=n		1	C_12_I_i, i=n	C_52_I_i, i=n
The distance between sphere and cylinder (D)	C_24	C_6_I_i; C_7_I_i, i=n			D_{6i} D_{7i} i=n	1	C_16_I_i; C_17_I_i, i=n	C_57_I_i; i=n
The distance between point and plane (E)	C_25	C_1_I_i; C_5_I_i, i=n	X_{1i} Y_{1i} Z_{1i} i=n	E_{5Xi} E_{5Yi} E_{5Zi} i=n		1	C_15_I_i, i=n	
The distance between sphere and plane (F)	C_26	C_6_I_i; C_5_I_i, i=n		E_{5Xi} E_{5Yi} E_{5Zi} i=n	D_{6i} i=n	1	C_16_I_i; C_15_I_i, i=n	
The angle between lines in the plane (G)	C_27	C_2_I_i, i=2n		E_{2Xi} E_{2Yi} E_{2Zi} i=2n		1	C_12_I_i; i=2n	C_52_I_i, i=2n
The angle between lines in the space (H)	C_28	C_2_I_i, i=2n		E_{2Xi} E_{2Yi} E_{2Zi} i=2n		1	C_12_I_i; i=2n	C_52_I_i, i=2n
The angle between line and plane (I)	C_29	C_2_I_i; C_5_I_i, i=n		E_{2Xi} E_{2Yi} E_{2Zi} E_{2Xi} E_{2Yi} E_{2Zi} i=n		1	C_12_I_i; C_15_I_i, i=n	C_52_I_i, i=n

In order to get a set of metrological information about the derived geometric characteristics of the measuring part (Fig. 2.), it is necessary to create the following new classes (Table 4): C_21; C_22; C_23; C_24; C_25; C_26; C_27; C_28; C_29, which are presenting derived geometric characteristics of the measuring part. Each class, defined by in this way, consists from one or more individuals that have been described via already defined individuals in paragraph 2.1 of this work, and which are unambiguously described the appropriate parameter (e.g. class C_21 consists of the individual C_21_I1, which is described via already defined individual C_1_I1 and C_1_I7, and wich are defined parameters, i.e. coordinates X11 Y11 Z11 , X11 Y11 Z11 respectively). Also, each class is uniquely described by the appropriate parameters, which together with the previous, leaving the possibility of integration with CAD software in purpose to export / import of these parameters. Number of the individual which participating in the description of new individuals depends on the type of derived geometric characteristics (eg class C_25 has one individual C_25_I1 described with 3i = 3n = 3-individual, and these are C_1_I5, C_1_I11 and C_5_I19).

3. IMPLEMENTING THE GEOMETRICAL PRIMITIVES IN THE SOFTWARE PROTÉGÉ

Software Protégé is a free, open sours ontology editor and knowledge – base framework, based on Java. At its core, Protégé implements a set of knowledge – modeling structures and actions that support the creation, visualization, and manipulation of ontologies in various representations formats [12]. In this paper is used Protégé – OWL editor that supports the Web Ontology Language, as most recent development in standard ontology language in purpose to development mini-ontology of the measuring part (Fig. 2.). OWL ontology includes description of classes, properties and individuals.

In this chapter, will be performed implementation of the proposed method of ontological modeling of geometrical primitives, which is given in the previous chapter, according to the modeling principles set out in [6, 13].

The implementation of metrology primitives of the part shown in Figure 3 in Protégé includes: 1) modeling classes, 2) modeling of class hierarchy, 3) modeling of the individual, 4) modeling properties classes and individuals (object and data properties).

Classes are represented geometrical primitives, which are organized in a hierarchy shown on Fig. 3. Individuals are represented in Protégé as the most specific class (e.g. class of points consists of more subclasses which are consists of appropriate number of individuals, which are also points that are defined across the properties).

3.1 ONTOLOGICAL DESCRIPTION IN RELATION TO THE COORDINATE SYSTEMS OF MEASURING PART

Participate following the classes C_i, i=1,…, 10. In Fig. 3. is shown a number of individuals that make up the class C_12. Between individuals from the class lines are also present in the individual classes of points, because the proposed model class of points used to describe the class lines.

This occurs as a consequence of existence a subclass C_1i, i = 1,2,3, ..., 9, class C_1. Also, C_5 class consists of subclasses K_52, C_53, C_54, C_57, C_58, C_59 and as a result of the fact that individuals plane (C_5_Ii) take part in the description of other classes such as C_2, C_3, C_4, C_7, C_8 and C_9. In Fig. 3. are shown three characteristics that fully describe the individual C_1_I1: coordinates x, y, z. For a description of the other individuals, are used to Data properties whose hierarchy is given in Figure 3 a). A link between two individuals is achieved by means of Object properties whose hierarchy is given in Fig. 3 b). Thus, Object Properties connects two or more individual while Data Properties describes the individual.

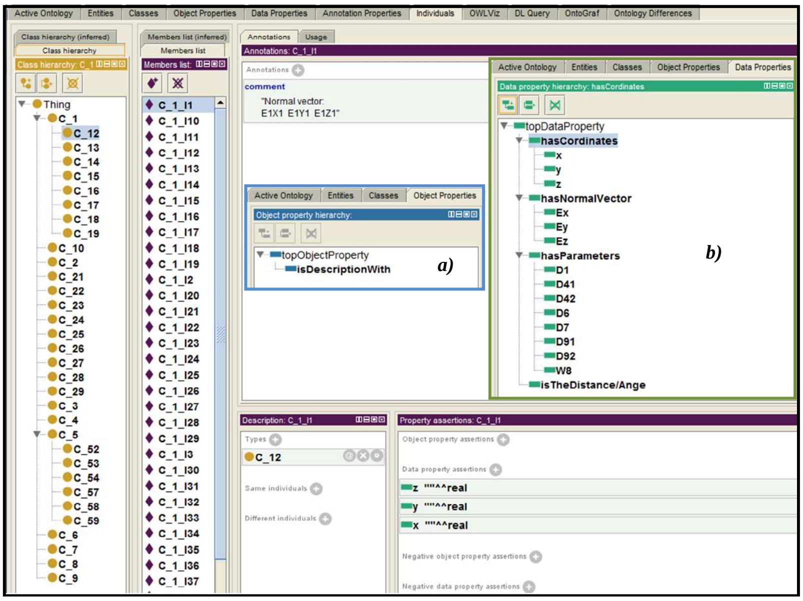

Fig. 3. A representation of classes, properties and individuals in Protégé: a) Object property hierarchy, b) Data property hierarchy

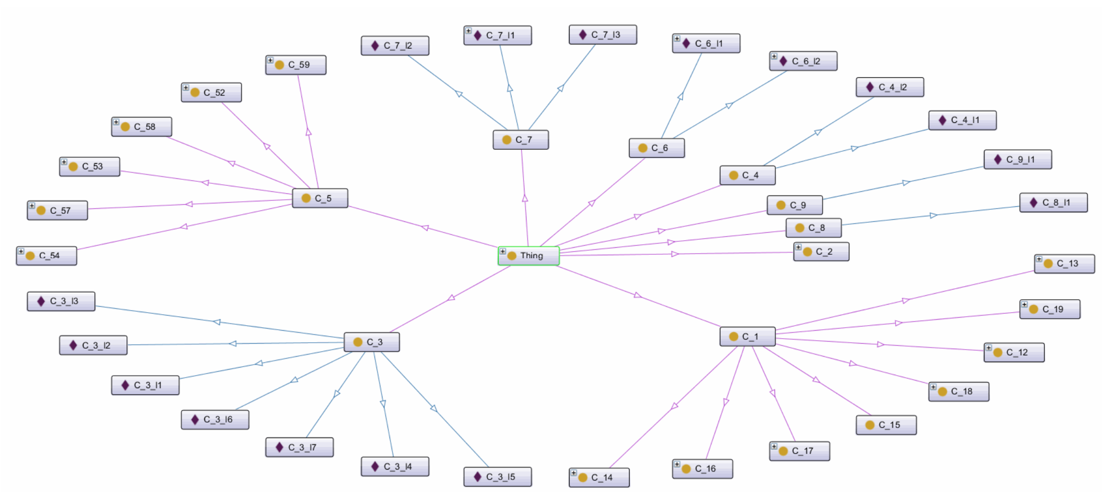

Fig. 4. A part of the OntoGraf - ontological description of the geometrical primitives in relation to the coordinate systems measuring part

3.2. ONTOLOGICAL DESCRIPTION IN RELATION TO THE COORDINATE SYSTEMS TASK

As described in the previous chapter, each derived geometric characteristics is described by two or more individuals (e.g. distance between two spheres is described by two spheres, which are already defined in this paper in section 2.1). However, in order to fully describe the derived geometric characteristics, it is necessary to further decompose these individuals (e.g. the distance between the two spheres is the distance between two points, that are centers of the spheres) until it does not fully describe the derived the geometric characteristics. After the introduction of new classes (see point 2.2 of this paper) C_2i, i = 1, ..., 9, it is necessary to describe their individual defined via an existing individuals with the help properties *IsDescriptionWith* (e.g. exactly determined distance between two spheres we defined as an individual who is described by two points). Defined individual is described with Data properties which represents the nominal value of the distance between two geometric primitives. In Figure 5 is shown OntoGraf, which the ontological describes all the derived geometrical characteristics measurement part.

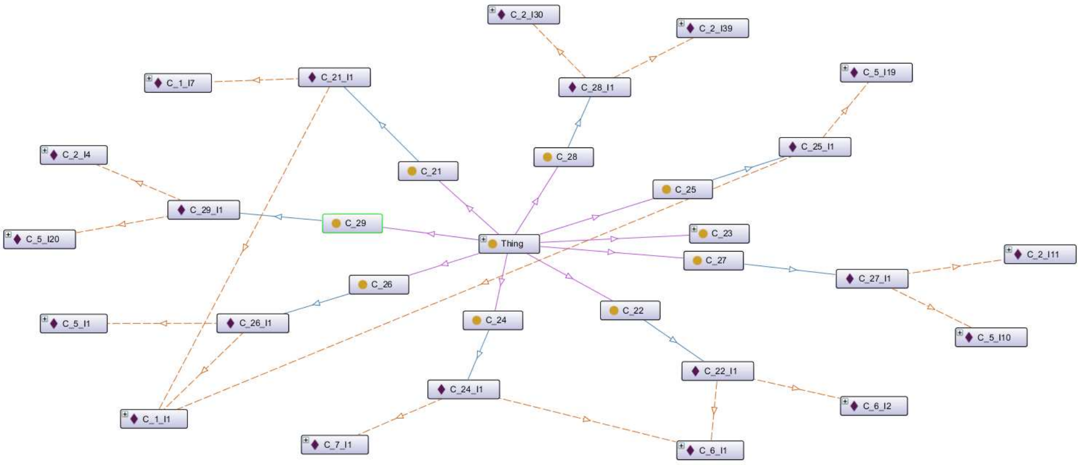

Fig. 5. A part of the OntoGraf - ontological description of the geometrical primitives in relation to the coordinate systems task

4. CONCLUSION

The paper defines the basic geometrical primitives as class of the engineering ontology in the field of production metrology in order to develop an information model for the CAI, based on the EO as an armature around which to build a knowledge base for metrology information about the ideal geometry in relation the coordinate system of measuring part and metrological information about the derived geometric characteristics of the measuring part. Defined the method of modeling basic geometrical primitives as classes, individuals and properties fully provides all the information about the ideal geometry of measuring part and the derived geometric characteristics. The proposed method is unique because each individual describes exactly defined parameters (Data properties) and hierarchy (Data properties hierarchy), and with the help of properties (Object properties) links individuals, by defining the metrological information about the ideal geometry in relation the coordinate system of measuring part and metrological information about the derived geometric characteristics of the measuring part. The result of the proposed method is a unique of classes hierarchy for all metrology parts that consist from the basic geometrical primitives. Implementation in Protégé showing that with the optimization of individuals within classes on the basis of metrological information about the measuring part, quite justified further develop CAI based on EO in the field production metrology.

ACKNOWLEDGEMENT

Some research results presented in this paper refer to the Projects supported by the Ministry of Science and Technology of Serbia, whose support are here emphasizes and expressing acknowledgement to it.

REFERENCES

[1] CHO, -W. M., LEE H., YOUN G.-S., CHOI J., 2005, *A feature-based inspection planning system for coordinate measuring machines*, International Journal of Advance Manufacturing Technology, 26-1078–1087, DOI 10.1007/s00170-004-2077-8.
[2] MAJSTOROVIĆ V., HODOLIČ J. 1998, *Numerički upravljane merne mašine,* Fakultet tehničkih nauka, Institut za proizvodno mašinstvo – Novi Sad, ISBN 86-499-0091-7.
[3] BARREIRO J., LABARGA J. E., VIZAN A., RIOS J., 2003, *Information model for the integration of inspection activity in a concurrent engineering framework,* International Journal of Machine Tools & Manufacture, 4- 797-809. doi: 10.1016/S0890-6955(03)00060-9.
[4] MARTINEZ-PALLITERO S., BARREIRO J., CUESTA E., ALVAREZ B. J., 2011, *A new process-based for KBE system implementation: application to inspection process planning*, International Journal of Advance Manufacturing Technology, DOI 10.1007/s00170-011-3285-7.
[5] DARTIGUES C., GHODOUS P., GRUNINGER M., PALLEZ D., SRIRAM R., 2007, *CAD/CAP Integration using Feature Ontology,* CONCURRENT ENGINEERING: Research and Applications, 15-2, DOI 10.1177/1063293X0707931.
[6] NOY N. F., MCGUINNESS D. L., 2001, *Ontology Development 101: A Guide to Creating Your First Ontology*, Tech. Rep. KSL-01-05 and SMI-2001-0800. Stanford, CA: Stanford University, Knowledge Systems Laboratory and Stanford Medical Informatics.
[7] STOJADINOVIC S., MAJSTOROVIC V., 2011, *Engineering ontology – state of the art and future development,* 6th International Working Conference "TOTAL QUALITY MANAGEMENT – ADVANCE AND INTELLIGENT APPROACHES, 7th-11th, June, Belgrade, Serbia, 54-58, ISBN 978-86-7083-727-0.
[8] ZHAO F., HABEEB S., XU X ., 2009, *Research into integrated design and manufacturing based on STEP*, International Journal of Advance Manufacturing Technology, 44-606–624, DOI 10.1007/s00170-008-1841-6.
[9] SOURLIER, D., 1995, *Three Dimenzional Feature Independent Bestfit in Coordinate Metrology,* Doctoral dissertation, Swiss Federal Institute of Tehnology Zurich.
[10] USCHOLD M., GRUNINGER M., 1996, *Ontologies: Principles, Methods and Applications, Knowledge Engineering Review,* 11(2).
[11] STOJADINOVIC S., MAJSTOROVIC V., 2011, *Metrological primitives in production metrology – ontological approach,* 34th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING, 29.-30. September, Nis, Serbia, 167-170, ISBN 978-86-6055-019-6.
[12] http://protege.stanford.edu/
[13] MATTHEW H. et al., 2009, *A Practical Guide to Building OWL Ontologies Using Protégé 4 and CO-DE Tools,* Edition 1.2, The University Of Manchester.