A TOOL TO SUPPORT PROJECT TIME EVALUATION

Bojcetic, Nenad (1); Zezelj, Dragan (1); Salopek, Damir (2); Valjak, Filip (1)
1: University of Zagreb, Croatia; 2: KONČAR - Power Transformers Ltd., Croatia

Abstract

The paper describes the development of a tool to support the project management process. The developed application enables project managers to estimate completion time for process of creation of CAD models. Application use real data retrieved from PLM system about previous projects so more accurate time could be make. The developed application was embrace by the project managers as the very valuable tool.

Keywords: Computer Aided Design (CAD), Project management, Product Lifecycle Management (PLM)

Contact:
Dr. Nenad Bojcetic
University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture
Croatia
nenad.bojcetic@fsb.hr

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1 INTRODUCTION

In the present state of market globalisation, it is even more challenging to get a new deal for your company. Knowing and understanding customer’s needs is at the centre of every successful business, whether it sells directly to individuals or other businesses. However, there is more to it than just knowing customer’s needs; one has to know and understand the whole process of production, and this is a lot of information. The research and findings presented in this paper are focused on the "Make To Order" process (Syska, 2006)

Negotiating a new project deal for the company is a stressful task and when a new project is worth millions of dollars or more it can be a nightmare. Every project request comes with a grey area that makes everyone nervous due to expectations concerning costs, timelines and level of effort. Since the grey area changes from project to project, there is no magical trick for creating a reliable estimate. In order to create a workable estimate, team leader needs to know a team, deliverables, tasks and process in more details as he can. Accurate time estimation is a skill essential for good project management. That is why any help is greatly appreciated. Of course, in today's modern companies' information technologies are unavoidable and ever-present and can support the negotiating efforts in many ways. Definitely, PLM is one of the strongest technologies that can provide much-needed information. If one want's to be a deal breaker, he or she has to be able to create the proposal that is cheaper then one from the competition but has to ensure profit for a company.

The design process is one of the most demanding and time-consuming tasks during product development (Ulrich, 2011). Even with support from various CAD and PLM applications and solutions, it is very hard to estimate its duration. In modern information systems that support design process, one of the widely used is CAD. However, the creation of the computer model of the product is dependent not only on designer's knowledge but also on his or her CAD skill level. For the same CAD model, different designers will complete the same model in different time. This is not a big problem when product computer model consists of several components. But when the product contains several thousand components than the slight variation in overall product configuration can lead to unforeseeable completion time.

How long it would take, for a new project, to complete CAD product computer models has a big impact on project time completion estimation. Because project completion time estimates often determine the pricing of contracts and hence the profitability of the contract/project in commercial terms. Absolute accuracy in time estimation for completion of CAD product computer models cannot be done but if this estimate can be determined to be as close as it can be (with reasonable margin), the project manager can significantly benefit from this information. It is a fact that the earlier the estimate is made, the less data we have available, and therefore the less “accurate” we can be (Huang, 2006). The only time we have sufficient data to truly warrant the label “accurate” is at the very end of the project when all the variables are resolved.

This article describes our approach on how to estimate the time needed for CAD product computer models completion. The first thought when thinking about the problem dealing with project time estimation is project management. Project management software can provide information that can support the process of calculating the time needed for CAD product computer models completion. But, project management software hasn't got the flexibility to play with different designer's assignments and to take into account his or her skill level. In addition, project management software licences cost a lot of money and take the time to learn. So, is there faster and easier way to get needed estimation? We think that combination of information from PLM and information from CAD models can give us enough data to create a tool that can support the process of project time estimation.

But, how to calculate the time needed for CAD product computer models to be completed? For example, Owensby (Owensby and Summers, 2014) presents an automated tool for estimating assembly times of products based on a three-step process: connectivity graph generation from assembly mate information, structural complexity metric analysis of the graph, and application of the complexity metric vector to predictive artificial neural network models. Also, Mathieson (Mathieson, Wallace and Summers, 2013) in his article presents an approach for the development of surrogate models predicting the assembly time of a system based on complexity metrics of the physical system architecture when detailed geometric information is unavailable. In our case, we are dealing (almost 90% of them) with already created product models which had to be altered to better suit new requirements. So, our approach is to look into

places where footprints of the CAD models are left in PLM and to look into CAD models and reason why it takes the longer time to complete one model in contrast to another. PLM system stores various information about the product and also about the CAD models. CAD model document lifecycle is one place where valuable information about time spent in CAD model creation. Every time user (designer) takes (Check out) CAD model from the PLM system and when he puts it back (Check in) timestamp is created. This timestamp can be retrieved from the PLM system, and we can calculate time elapsed from one document cycle (Check out, Check in). This time describes a time it takes for the designer to complete tasks he needs to do on a model. Of course, this work can involve much more than just creation or alteration of CAD model. Doing calculations, browsing the catalogues, consulting with colleagues or literature, having meetings, or just thinking about the task. When you think about this, this is something that every designer will do when given particular task. But designer with higher CAD skill level will complete the CAD model in the shorter time than another one given the same task. In our work, we are not trying to evaluate designer knowledge about the design but just his skill level in the usage of CAD software. That is why our point of view is that time from checking out the document till checking it back in can be considered the time needed for completion of a CAD model.
When working on the project, it is customary to have several document cycles and each of them represents a small change in the CAD model. It is worth mentioning that we are interested only in a cycle of the CAD documents not in other documents that are created or edited during the design process. Even though our approach could be extended to involve other document created or edited during the design process. A CAD document is considered completed when it is approved and released. From the information about all the versions of the final CAD model, we calculate the time elapsed from the creation or introduction of the CAD model until it is released and ready for next phase. Another information from the data retrieved from the PLM system about the CAD model that is of interest for our data model is the information about the user or users that did (created or changed) a particular model. This information will be subsequently placed in context with information on CAD models.
To make assumption what makes one CAD model different from the other the structure of the average CAD model has to be analysed. That is why we consulted the literature first, and then we analysed existing CAD models of the parts of the power transformer. Here, we limit analysis only to 3D CAD models created using a FBD (Feature-Based Design) approach.
Data, CAD models and project information used in our research were provided by the designers and employees of the Koncar Power Transformers (KPT). Except for the provided information, KPT also dedicated a couple of experienced designers to work with our research team. Koncar Power Transformers is using CREO 2.0 as a core CAD application and Windchill 10.1 is used as the PLM system. After successful adoption of the PLM solution four years ago KPT (Bojcetic, 2015) is introducing one by one major component of the power transformer into the Windchill. Today, almost 140 projects were released using Windchill and supported technologies.

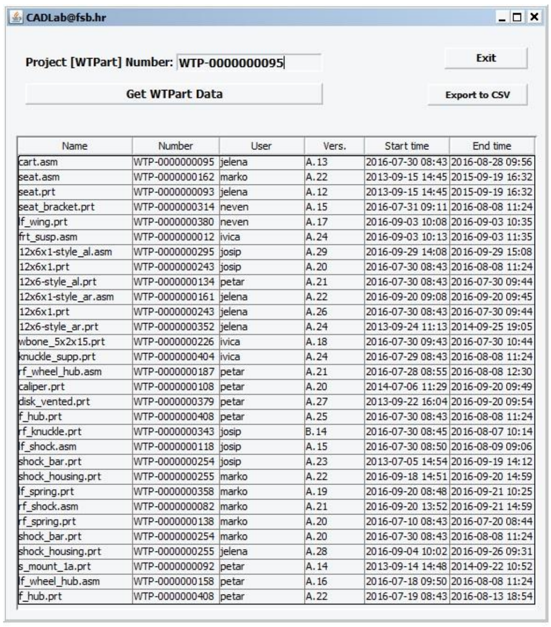
2 THE PROTOTYPE APPLICATION

Now that we have relevant data we start building the prototype application. The application was created partially in the Excel (using macros and stored data) and partially as the external DLLs (Dynamic Linked Library). The DLLs were used for mathematical calculations, and they are called from Excel macros. The Excel is used both as the data storage (simple database) and as the host application. Data storage part consists of the two sheets. One sheet holds project's list of products and parts while the other holds the data about the users and corresponding fitting function.

2.1 The Implementation

Analysing the PLM data model schema, it can be noticed that every schema involves the same basic properties of the product. This is a number, name, version, user, revision and the creation date and the date of final release. Some PLM applications do not store information about all the versions of the particular document but just a few.
The number of stored document versions does not have an influence on the document release date. To be able to analyse the data about the product, the application that will retrieve the data from the PLM system was created. Firstly, usage of query/report creation module was considered. But in Windchill PLM system, query cannot traverse the product (CAD) structure. This is a problem because product specific CAD document’s data had to be retrieved, not the data about CAD documents from different

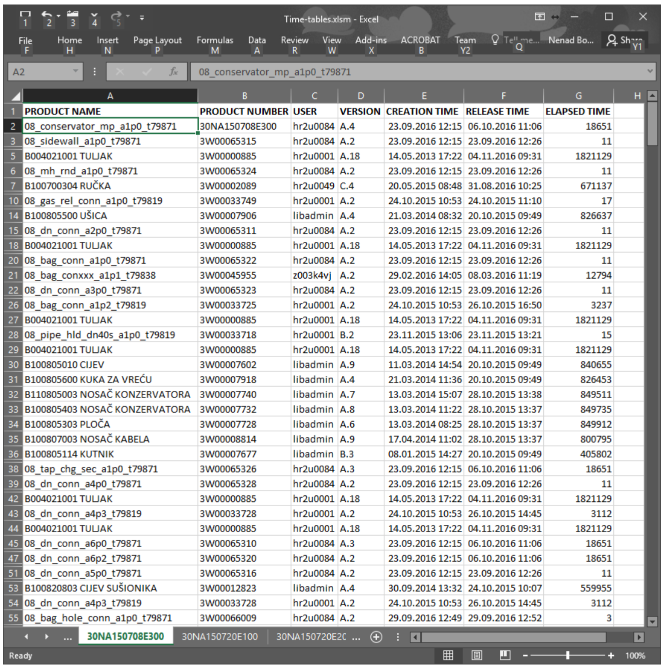
products. Application for product data retrieval (*WcTProdData*) was created using Windchill Java API and Swing library. Product number was used as the initial information for project selection. The product number is important because this is the unique identifier for every object in the PLM system. Based on the product number the application retrieves rest of the needed information. In Figure 1. the application main window and the part of extracted data can be seen.



Name	Number	User	Vers.	Start time	End time
cart.asm	WTP-0000000095	jelena	A.13	2016-07-30 08:43	2016-08-28 09:56
seat.asm	WTP-0000000162	marko	A.22	2013-09-15 14:45	2015-09-19 16:32
seat.prt	WTP-0000000093	jelena	A.12	2013-09-15 14:45	2015-09-19 16:32
seat_bracket.prt	WTP-0000000314	neven	A.15	2016-07-31 09:11	2016-08-08 11:24
lf_wing.prt	WTP-0000000380	neven	A.17	2016-09-03 10:08	2016-09-03 10:35
frt_susp.asm	WTP-0000000012	ivica	A.24	2016-09-03 10:13	2016-09-03 11:35
12x6x1-style_al.asm	WTP-0000000295	josip	A.29	2016-09-29 14:08	2016-09-29 15:08
12x6x1.prt	WTP-0000000243	josip	A.20	2016-07-30 08:43	2016-08-08 11:24
12x6-style_al.prt	WTP-0000000134	petar	A.21	2016-07-30 08:43	2016-07-30 09:44
12x6x1-style_ar.asm	WTP-0000000161	jelena	A.22	2016-09-20 09:08	2016-09-20 09:45
12x6x1.prt	WTP-0000000243	jelena	A.26	2016-07-30 08:43	2016-07-30 09:44
12x6-style_ar.prt	WTP-0000000352	jelena	A.24	2013-09-24 11:13	2014-09-25 19:05
wbone_5x2x15.prt	WTP-0000000226	ivica	A.18	2016-07-30 09:43	2016-07-30 10:44
knuckle_supp.prt	WTP-0000000404	ivica	A.24	2016-07-29 08:43	2016-08-08 11:24
rf_wheel_hub.asm	WTP-0000000187	petar	A.21	2016-07-28 08:55	2016-08-08 12:30
caliper.prt	WTP-0000000108	petar	A.20	2014-07-06 11:29	2016-09-20 09:49
disk_vented.prt	WTP-0000000379	petar	A.27	2013-09-22 16:04	2016-09-20 09:54
f_hub.prt	WTP-0000000408	petar	A.25	2016-07-30 08:43	2016-08-08 11:24
rf_knuckle.prt	WTP-0000000343	josip	B.14	2016-07-30 08:45	2016-08-07 10:14
lf_shock.asm	WTP-0000000118	josip	A.15	2016-07-30 08:50	2016-08-09 09:06
shock_bar.prt	WTP-0000000254	josip	A.23	2013-07-05 14:54	2016-09-19 14:12
shock_housing.prt	WTP-0000000255	marko	A.22	2016-09-18 14:51	2016-09-20 14:59
lf_spring.prt	WTP-0000000358	marko	A.19	2016-09-20 08:48	2016-09-21 10:25
rf_shock.asm	WTP-0000000082	marko	A.21	2016-09-20 13:52	2016-09-21 14:59
rf_spring.prt	WTP-0000000138	marko	A.20	2016-07-10 08:43	2016-07-20 08:44
shock_bar.prt	WTP-0000000254	marko	A.20	2016-07-30 08:43	2016-08-08 11:24
shock_housing.prt	WTP-0000000255	jelena	A.28	2016-09-04 10:02	2016-09-26 09:31
s_mount_1a.prt	WTP-0000000092	petar	A.14	2013-09-14 14:48	2014-09-22 10:52
lf_wheel_hub.asm	WTP-0000000158	petar	A.16	2016-07-18 09:50	2016-08-08 11:24
f_hub.prt	WTP-0000000408	petar	A.22	2016-07-19 08:43	2016-08-13 18:54

Figure 1. Application for product data retrieval

Because of the fact that company is using a product as a basis for managing project data, retrieved project information can also be considered as product relevant information. About 140 projects data were retrieved from the PLM system information. Each project consists of four or five products. The retrieved information was stored in separate files; each file represents data from one project (Figure 2.). The retrieved information was subsequently inserted into the sheets in the Excel. In Excel, a macro was created to calculate time elapsed from each model creation until its release.



	A	B	C	D	E	F	G
1	PRODUCT NAME	PRODUCT NUMBER	USER	VERSION	CREATION TIME	RELEASE TIME	ELAPSED TIME
2	08_conservator_mp_a1p0_t79871	30NA150708E300	hr2u0084	A.4	23.09.2016 12:15	06.10.2016 11:06	18651
3	08_sidewall_a1p0_t79871	3W00065315	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
5	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
6	08_mh_rnd_a1p0_t79871	3W00065324	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
7	B100700304 RUČKA	3W00002089	hr2u0049	C.4	20.05.2015 08:48	31.08.2016 10:25	671137
10	08_gas_rel_conn_a1p0_t79819	3W00033749	hr2u0001	A.2	24.10.2015 10:53	24.10.2015 11:10	17
14	B100805500 UŠICA	3W00007906	libadmin	A.4	21.03.2014 08:32	20.10.2015 09:49	826637
15	08_dn_conn_a2p0_t79871	3W00065311	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
18	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
20	08_bag_conn_a1p0_t79871	3W00065322	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
21	08_bag_conxxx_a1p1_t79838	3W00045955	z003k4vj	A.2	29.02.2016 14:05	08.03.2016 11:19	12794
22	08_dn_conn_a3p0_t79871	3W00065323	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
26	08_bag_conn_a1p2_t79819	3W00033725	hr2u0001	A.2	24.10.2015 10:53	26.10.2015 16:50	3237
27	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
28	08_pipe_hld_dn40s_a1p0_t79819	3W00033718	hr2u0001	B.2	23.11.2015 13:06	23.11.2015 13:21	15
29	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
30	B100805010 CIJEV	3W00007602	libadmin	A.9	11.03.2014 14:54	20.10.2015 09:49	840655
31	B100805600 KUKA ZA VREĆU	3W00007918	libadmin	A.4	21.03.2014 11:36	20.10.2015 09:49	826453
32	B110805003 NOSAČ KONZERVATORA	3W00007740	libadmin	A.7	13.03.2014 15:07	28.10.2015 13:38	849511
33	B100805403 NOSAČ KONZERVATORA	3W00007732	libadmin	A.8	13.03.2014 11:22	28.10.2015 13:37	849735
34	B100805303 PLOČA	3W00007728	libadmin	A.6	13.03.2014 08:25	28.10.2015 13:37	849912
35	B100807003 NOSAČ KABELA	3W00008814	libadmin	A.9	17.04.2014 11:02	28.10.2015 13:37	800795
36	B100805114 KUTNIK	3W00007677	libadmin	B.3	08.01.2015 14:27	20.10.2015 09:49	405802
38	08_tap_chg_sec_a1p0_t79871	3W00065326	hr2u0084	A.3	23.09.2016 12:15	06.10.2016 11:06	18651
39	08_dn_conn_a4p0_t79871	3W00065328	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
42	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
43	08_dn_conn_a4p3_t79819	3W00033728	hr2u0001	A.2	24.10.2015 10:53	26.10.2015 14:45	3112
44	B004021001 TULJAK	3W00000885	hr2u0001	A.18	14.05.2013 17:22	04.11.2016 09:31	1821129
45	08_dn_conn_a6p0_t79871	3W00065310	hr2u0084	A.3	23.09.2016 12:15	06.10.2016 11:06	18651
47	08_dn_conn_a6p2_t79871	3W00065320	hr2u0084	A.2	23.09.2016 12:15	06.10.2016 11:06	18651
51	08_dn_conn_a5p0_t79871	3W00065316	hr2u0084	A.2	23.09.2016 12:15	23.09.2016 12:26	11
53	B100820803 CIJEV SUŠIONIKA	3W00012823	libadmin	A.4	30.09.2014 13:32	24.10.2015 10:07	559955
54	08_dn_conn_a4p3_t79819	3W00033728	hr2u0001	A.2	24.10.2015 10:53	26.10.2015 14:45	3112
55	08_bag_hole_conn_a1p0_t79871	3W00066009	hr2u0084	A.2	29.09.2016 12:49	29.09.2016 12:52	3

Figure 2. Representation of product data retrieved from the PLM system

Next step was to calculate complexity factor for each CAD model. Rodríguez-Toro et.al (2002) states that complexity in design is considered about component geometry where it has been studied for its influence in many areas. This research can be classified according to the following categorisations: geometry, topology and assembly. Rossignac (2005) on the other hand classifies complexity as:

- Algebraic complexity - measures the degree of polynomials needed to represent the shape exactly in its implicit or parametric form.
- Topological complexity - measures the number of handles and components or the existence of non-manifold singularities, non-regularized components, holes or self-intersections.
- Morphological complexity - measures smoothness and feature size.
- Combinatorial complexity - measures the vertex count in polygonal meshes.
- Representational complexity - measures the footprint and ease-of-use of a data structure or the storage size of a compressed model.

Summers (Summers and Shah, 2003) measure complexity of the product (also applicable to process and problem) based on the its size, coupling and solvability. Many papers deal with problem of complexity of creating mesh for various FEM analysis (King, 1999) (White, 2003) and how to reduce the complexity of such models for various purposes (Woodwark, 1982) (Thakur, 2009) (Suh, 2005).

Based on the reviewed articles, information from books and our findings the method for calculation of complexity of CAD model is proposed. Designers during their everyday work on the creation of CAD models argued that a number of various objects that have to be created or modified have a significant impact on the complexity of CAD model. Here, we need to state that in our viewpoint of complexity no dynamic elements were considered. In proposed method for calculation of complexity of CAD model the complexity is calculated by adding the following data:

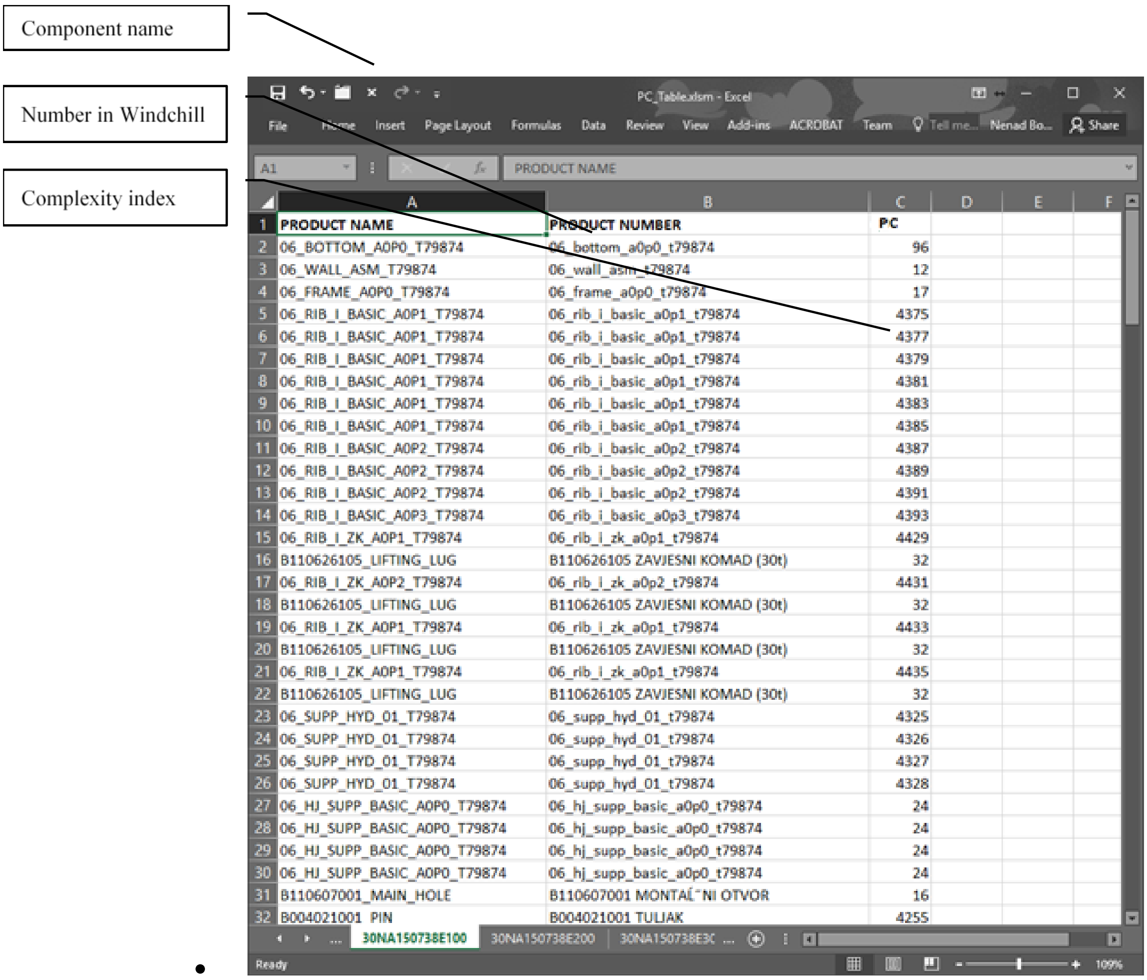
- The number of geometrical objects (lines, splines, points, …) in sketch;
- The number of geometrical relations between geometrical objects in the sketch;
- The number of features in part;
- The number of relations between features (repeated relations are not considered);
- The number of parameters;
- The number of relations.

Based on the proposed method for calculation of complexity of CAD model, the application (PCCalc) was created. Because of the fact that all product CAD models are stored in the PLM application the PCCalc was created to be able to retrieve model directly from the Windchill workspace. PCCalc was created using CREO/Toolkit API. Excerpt from the visiting method for calculation of number of objects in the sketch can be seen in the Figure 3.

The complexity calculated by the PCCalc application from the available product's CAD models are captured and inserted in the Excel sheets. Part of the calculated data is shown in Figure 4.

```
feature = (ProFeature*)p_modelitem;
status = ProModelitemDefaultnameGet(feature, fwname);
ProWstringToString(fsname, fwname );
status = ProFeatureTypeGet(feature, &ftype);
status = ProFeatureTypenameGet(feature, feattypename);
ProWstringToString(ftname, feattypename);
feat_num++;
status = ProFeatureChildrenGet(feature, &children_ids, &n_children);
childrenNo += n_children;
if (status == PRO_TK_NO_ERROR){
   status = ProUtilFeatureSectionGet(*feature, &section);
   if (nosection == 0){
      if (status == PRO_TK_NO_ERROR){
        status = ProSectionEntityIdsGet(section, &ent_ids, &n_ids);
        if (n_ids > 0) geomNo += n_ids;
      }
      if (status == PRO_TK_NO_ERROR){
        status = ProSecdimIdsGet(section, &dim_ids, &n_dimids);
        if (n_dimids > 0) dimsNo += n_dimids;
      }
      if (status == PRO_TK_NO_ERROR){
        status = ProSectionConstraintsIdsGet(section, &con_ids, &n_conids);
        if (n_conids > 0) constrNo += n_conids;
      }
   }
}
```

Figure 3. Excerpt from the visiting method (CREO/Toolkit)



	A	B	C
1	PRODUCT NAME	PRODUCT NUMBER	PC
2	06_BOTTOM_A0P0_T79874	06_bottom_a0p0_t79874	96
3	06_WALL_ASM_T79874	06_wall_asm_t79874	12
4	06_FRAME_A0P0_T79874	06_frame_a0p0_t79874	17
5	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4375
6	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4377
7	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4379
8	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4381
9	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4383
10	06_RIB_I_BASIC_A0P1_T79874	06_rib_i_basic_a0p1_t79874	4385
11	06_RIB_I_BASIC_A0P2_T79874	06_rib_i_basic_a0p2_t79874	4387
12	06_RIB_I_BASIC_A0P2_T79874	06_rib_i_basic_a0p2_t79874	4389
13	06_RIB_I_BASIC_A0P2_T79874	06_rib_i_basic_a0p2_t79874	4391
14	06_RIB_I_BASIC_A0P3_T79874	06_rib_i_basic_a0p3_t79874	4393
15	06_RIB_I_ZK_A0P1_T79874	06_rib_i_zk_a0p1_t79874	4429
16	B110626105_LIFTING_LUG	B110626105 ZAVJESNI KOMAD (30t)	32
17	06_RIB_I_ZK_A0P2_T79874	06_rib_i_zk_a0p2_t79874	4431
18	B110626105_LIFTING_LUG	B110626105 ZAVJESNI KOMAD (30t)	32
19	06_RIB_I_ZK_A0P1_T79874	06_rib_i_zk_a0p1_t79874	4433
20	B110626105_LIFTING_LUG	B110626105 ZAVJESNI KOMAD (30t)	32
21	06_RIB_I_ZK_A0P1_T79874	06_rib_i_zk_a0p1_t79874	4435
22	B110626105_LIFTING_LUG	B110626105 ZAVJESNI KOMAD (30t)	32
23	06_SUPP_HYD_01_T79874	06_supp_hyd_01_t79874	4325
24	06_SUPP_HYD_01_T79874	06_supp_hyd_01_t79874	4326
25	06_SUPP_HYD_01_T79874	06_supp_hyd_01_t79874	4327
26	06_SUPP_HYD_01_T79874	06_supp_hyd_01_t79874	4328
27	06_HJ_SUPP_BASIC_A0P0_T79874	06_hj_supp_basic_a0p0_t79874	24
28	06_HJ_SUPP_BASIC_A0P0_T79874	06_hj_supp_basic_a0p0_t79874	24
29	06_HJ_SUPP_BASIC_A0P0_T79874	06_hj_supp_basic_a0p0_t79874	24
30	06_HJ_SUPP_BASIC_A0P0_T79874	06_hj_supp_basic_a0p0_t79874	24
31	B110607001_MAIN_HOLE	B110607001 MONTAĹ˝NI OTVOR	16
32	B004021001_PIN	B004021001 TULJAK	4255

Figure 4. Product complexity data

In the Excel workbook containing data about product, user and completion time, a macro was created to extract data about products and the corresponding time for each user. This data along with data about product complexity were used to create time-complexity diagrams (Figure 5.).

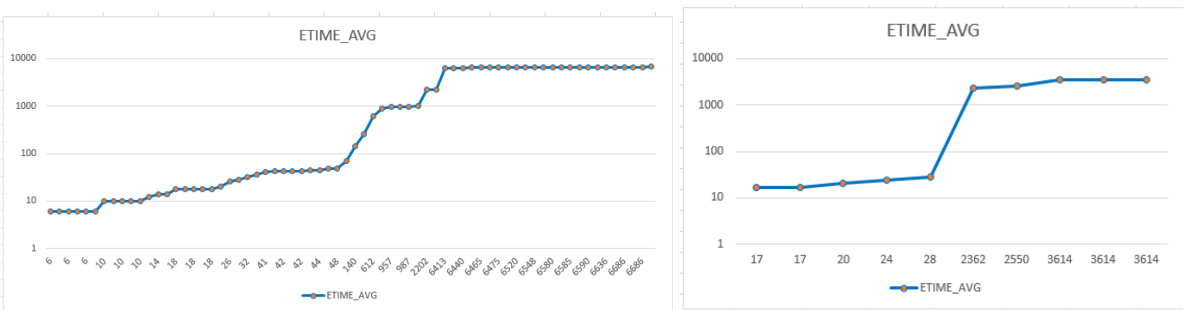


Figure 5. Time-complexity diagrams (for two different users)

Using regression analysis method, the function that describes a relation between the part complexity index and the part completion time was inferred. Regression analysis was done for every user. These functions were used to calculate the time needed to complete particular product by the particular user. For the most of the analysed user's (time-complexity) diagrams interpolation function was the logistic function (Equation (1)), but for a couple of users, this was not true.

$$f(et) = \frac{L}{1+e^{-k(pc-pc_0)}} \qquad (1)$$

Where et represents estimated time, L represents the curve's maximum value, k is the steepness of the curve; the pc_0 represents the x-value of the Sigmund's midpoint. Coefficients in the formula are calculated for every user based on the data retrieved from the Windchill.

3 THE PROOF OF CONCEPT

The prototype application was tested using students' help. During last semester students were working on group assignments, designing various mechanical parts (products). For each assignment, they had to create 3D CAD computer model of the product. Overall, the 15 students created about 30 viable products. Products were various gadgets (assembles) used to secure parts during machining. Students were from their third year of study and there are proficient in usage of SolidWorks but not in usage of CREO. They finished CREO basic training. The assignments were individual and the students had to do their work in the classrooms under assistant supervision. In their work, they had to use Windchill PLM application and CREO for the creation of CAD models. The data about each product (completion time and user data) was stored in the Windchill database. The data from the Windchill and the CAD models were analysed. This time fitting function, resembled the linear function ($et = a \cdot pc + b$) almost for every student. The explanation for this was found in the fact that students worked, in disciplined way, in checking out models when they had something to do and checking in models immediately when they finished with their work. The fact is that this is not possible in a real work environment because of the various external influences such as communication with co-workers, doing additional tasks, etc. But for the sake of proof of concept, this is considered not relevant.

Next, students were asked to create 3D CAD model of another product, but this time they were not given the same part as in their original assignment. Before the students were given their assignments, the prototype application was used to create assignments and to calculate each project completion time estimation. The same process was repeated for ten different projects/products. Time spent for 3D CAD model creation was additionally recorded manually by students. Then the data from Windchill (about the completion time for each part) was retrieved and overall project/product completion time was calculated. That time was compared with estimated time done using prototype application and time recorded manually by students.

The comparison showed that time retrieved and calculated from Windchill was 3% off to manually recorded time and prototype application was 15% off in plus side then manually recorded time and 6% off in plus side then time retrieved and calculated from Windchill.

According to conducted analysis of retrieved data we tried a couple of different fitting functions (linear, parabolic and 3-degree curve) for calculating time. After comparison with data from the first estimation, it was evident that S curve fitting function was the best solution.

4 THE WINDCHILL IMPLEMENTATION

Data gathered from the prototype application testing were once more analysed and checked. Based on this analysis, the application that will be implemented in the Windchill application was conceived. In the creation of this application, we had to rely directly on the data from the Windchill database not from the offline files like in prototype application. The application was created using Windchill Java API and swing library for GUI creation (Figure 6.). The application usage scenario is as follows:

- Project manager starts the application using Windchill as the loader: *windchill -cp hr.fsb.cadlab.MainApp*
- In the opened window project manager has to select previous project/product he or she wants to use as the template.
- The application retrieves product structure from the Windchill database and the name of the user that was responsible for CAD model creation. During data retrieval (for now) application send the product to the workspace and involves Creo (in the background, without front GUI) to calculate complexity for each part. Why "for now"? It is because our intention is to add complexity calculation as the part of the Release procedure in the Release workflow eventually. Currently, this is not possible because any alteration or change in Windchill implementation can generate serious problems. But the company has the plan to upgrade to Windchill release 10.2 or 11.0 (now they are using 10.1), and after the upgrade, all workflows will be tested and upgraded with the new functionalities so our customizations can also be implemented.

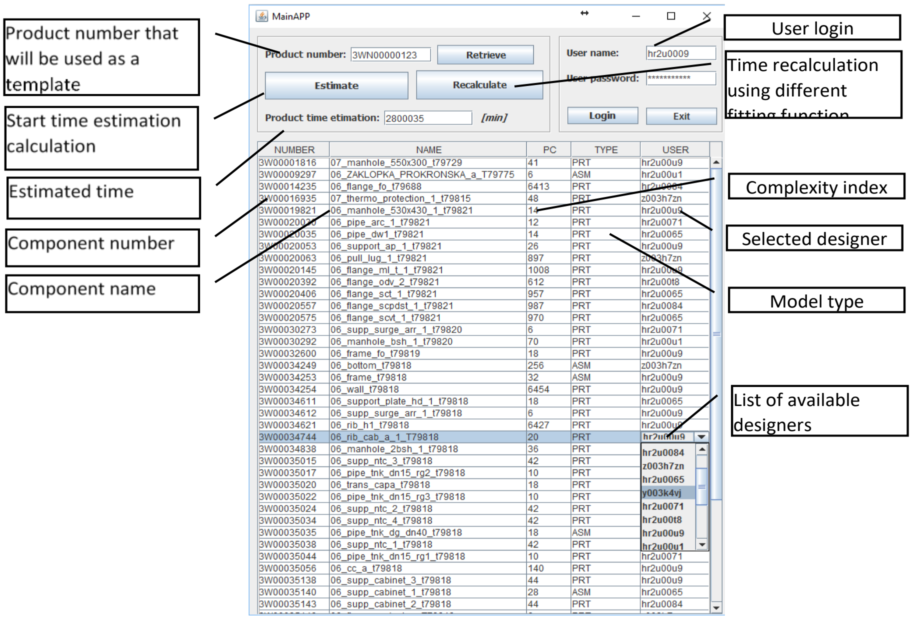


Figure 6. Main application GUI

- In the main application window, the project manager can see product structure (on the left side) and responsible user for a particular part (on the right side), user control is a combo box where all other users' names are also available. The other users (usernames) are collected from the Windchill database based on their involvement in the creation of CAD models (the user who is not responsible for the creation of any CAD model is not considered). The project manager can freely select any user from the list. After the user has been selected, the application retrieves data from the Windchill database needed for calculation of fitting function. For the users that were chosen earlier (in another application execution), the fitting function is stored in the Windchill database as a property of the user (project manager can involve fitting function recalculation).
- After the project manager made all the settings, the estimation of the time needed for completion of the CAD models is calculated.
- Now project manager can change his or her selection and try to find users combination that fit his or her requirements.

Application algorithm is as follows:

- On application start user have to select existing product giving its product number. This number is used to retrieve product components.
- According to the product number right product is selected and all objects (WTParts) that have associated CAD model (EPMDocument) are collected. Rest of the objects (the objects of the different class that are a part of the product structure) are excluded, this is achieved through usage of SQL type query. During this step time elapsed from the first CheckIn until the Release is calculated. Information about the user in charge of model creation is associated with the object been processed. Because of the fact that user is also an object only unique identifier of particular object (user) is stored (namely user's login name).
- Retrieved EPMDocument objects are (one by one) opened in the CREO (running on the server in the batch – without GUI) and the part of the application (CREO DLL) responsible for calculation of complexity index is executed.
- When all EPMDocument are processed, the control is return to the main application (a message is sent with data regarding each model complexity index). Now the application calculates average time for each user that it takes him to create part of particular complexity. This time is associated with user unique identifier and will be used later in calculation time that a user takes to complete a CAD model.
- Now all the required data are prepared and are displayed in the main window.
- If product manager for particular component selects different user a function for calculating completion time is called. This function, based on available data, calculates time a newly selected user will take to complete particular part and displays this information in the main window. This

functionality enables the product manager to "play" with different user schema based on the current or foreseeable user availability.

- Recalculation option gives a product manager to try different fitting function for prediction of user time needed to complete a model (this option is for testing purposes only and will be removed later). Estimate command calculates overall time for product to be completed based on the current configuration.

After initial implementation and run the first problem has emerged. The problem was created by all other types of documents that accompany a product and are not relevant to the product CAD structure. So, the filter had to be inserted in a piece of code responsible for product structure retrieval to filter out all non-*EPMDocuments*. The second problem was with erratic fitting function calculation for some users. The source of this problem were users responsible for maintaining libraries and components that did not require any alteration except from given a new number. Users responsible for maintaining libraries just manipulate the CAD parts and they rarely create one, so, their time working on the CAD parts is very short. This is also the case with components that are just used not created or altered. These components can have high complexity value but time spend in their preparation is very short. That is why those users and components were also filtered out.

The first testing was done by selecting the same users that were involved creation of product models. The estimated completion time was 12% off in plus side. Full application potential was difficult to analyse because average project time duration from project start till project completion is about four months. Until now 10 simulations and one real project data were collected. Simulations were, as stated before, showing difference from the actual project time completion to the estimated one about 12% in plus side. The analysis of real collected data has shown that the estimation was off by 26% in plus side. This was assigned to the way of fitting function calculation. So, the new algorithm (linear interpolation) is added enabling the project manager to choose between fitting functions he or she wants to use. Recalculating time estimation using a new function on the same data gave us an estimation time only 14% off in the plus side.

5 CONCLUSION

Estimating project time duration is one of the most difficult tasks in project management. That is why any tool that can support this process is appreciated. During long discussions with people that are involved in project management, it was evident that what they need is a tool that can quickly give them time estimation for various tasks. One of those tasks is CAD models creation, and this is the problem that we tried to tackle in our research project. As a result, from this project, application to support CAD models completion time estimation was developed. Analysis of the data retrieved from the PLM system showed that everything needed for the completing project goal stored is in PLM system. But, data had to be analysed and scrutinised so that it will become suitable for application implementation. The hardest thing was to interpret data retrieved from the PLM system and to make sense why some data is out of expected value or form. For the quarter of users fitting function resembled S curve and for rest of them it resembled a line. Analysis showed that this can be mainly credited to the usage of Creo customizations in model variant creation. The approach presented in the article was proven sound. Data gathered from prototype and test implementation were found usable. The next step is to monitor application usage and to articulate data from application with real data when each project is finished. The application usage will provide information on how often and by who the application is used (this is achieved by the application itself because each usage is documented). After couple of months of application usage an interview will be conducted with users that used the application and their experience will be captured and later on analysed. This will be used as the guidelines for the application improvement and also as the indicator if application is useful or not. The results of the data analyse from the interviews will be presented to the firm management and they will make decision if application will be used in every day work or the solution is not viable.

One complaint from the project managers was about the time spent by application on data preparation for products consisting of about five thousand and more components. The culprit for this problem was found in usage of webjects (it turns out that webjects executes much slower than pure java code). Currently a new version of application has been implemented. In addition, a team is working on another approach, to implement application like a service rather than standalone. During discussion with the project managers interested in the application usage the conclusion was achieved that the application, if enters work practice, will greatly enhance current project time completion estimation process.

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