

Specification of Finite Element Model of Electronic Device using Model-driven Wizard-based Guidance

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Introduction

The modeling of the fields of electronic devices of any kind is widely researched. Currently, in this activity more emphasis is being attributed to the following kinds of research: the improvement of intrinsic features of the modeling process itself and the continuous improvement of support for building models. In this paper we are addressing the latter problem by introducing the idea of applying the model-based guided process for specifying finite element models (FEM) of electronic devices [1–3].

Connection between System Engineering and Software Engineering issue is solved by applying principles of Model-Driven Engineering (MDE). MDE considers models as first class entities. This is important trend in the software engineering industry, which intent is to raise the level of abstraction and move from textual programming languages like Java, C++ or C# to visual modeling languages like UML [4] as the main software systems implementation means.

This paper presents a usage of the model-driven development framework called *MD Wizard* – MagicDraw plug-in [5] for creating custom wizards for supporting specification of finite element models of electronic devices.

We present the UML based profile for FEM of electronic devices and executable, customized Wizard based on Software Process Engineering Metamodel (SPEM) [6]. The Wizard provides the guidance through process of specifying FEM and allows generating a software code from the specified model.

Parametrization of the finite element model

Simple parametrizations of modeling process of fields of electronic devices aiming to find the optimal solution are being applied in many cases. This approach requires to build the model and to select a certain parameter regarding which the optimization will take place. This is a convenient technique, but it is not sufficient when some radical modifications of the model (e.g. replacement of model

components) have to be made. This obstacle can be overcome by splitting the entire modeling process into separate stages and defining parameters for each modeling stage [1].

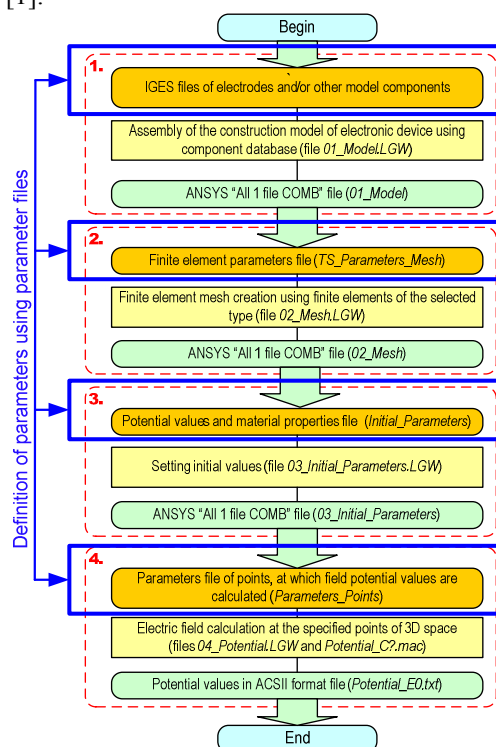


Fig. 1. Electronic device electric field modeling algorithm

A universal definition of components (and in turn of the overall model) is not possible since the number of the geometry-related parameters is practically different for all electronic devices. Therefore, this technique will render a different success for each practical case. For example, devices of electron optics are a convenient area of building parameterized finite element models, because devices of this type have the relatively simple construction. Similar design approach can be also applied to other types of electronic devices having modular construction. Algorithm

for this process (i.e. modeling of electric field potential) is illustrated in Fig. 1 [2]. Here the stages which use parametric definition of modeling stages are indicated by arrows, and numbers indicate the main stages of the modeling process: 1) creation of the geometry model; 2) definition of finite element mesh parameters; 3) setting of the initial and boundary values; and 4) defining the solution parameters and solving the problem.

Creation of the geometric model of a single component of the particular electronic device consists of the definition of its geometric features. One typical example of the geometry parameters of a single electrode (according to Fig. 2) is presented in Table 1.

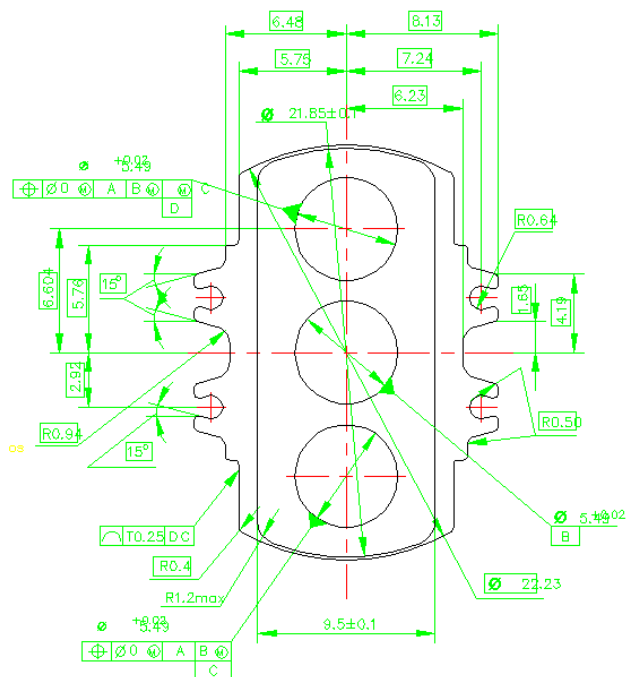


Fig. 2. Example of the electrode drawing with the dimensions indicated

Naming conventions of geometry parameters may vary; in this case (when there are several similar parameters) a number indicates the index of the particular parameter. When assembling the overall construction model the spatial coordinates of each component have to be specified also. The example of such definition (fragment from ANSYS command file) is given in Fig. 3.

Table 1. Example list of geometry parameters of a single electronic device component (electrode)

Width, mm	W1	W2	W3	W4	W5
	6.48	5.75	8.13	7.24	9.50
Diameter, mm	D1	D2	D3	D4	D5
	5.49	5.49	5.49	22.23	21.85
Radius, mm	R1	R2	R3	R4	R5
	0.64	0.50	1.20	0.40	0.94
Length, mm	L1	L2	L3		
	6.60	5.76	2.29		
Angle, deg	A1	A2			
	15	15			

The following stage – mesh creation – may be based on several decisions. These decisions are: 1) selection of the finite element type; 2) definition of the finite element mesh spacing; 3) definition of the mesh spacing increase (or decrease) factor (required for analysis of mesh spacing influence on modeling results); 4) placement of the base

nodes for interpolation (if required).

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Component name
CDREAD, SOLID, , , , 'E1', 'iges', , '
FLST, 3, 1, 6, ORDE, 1
FITEM, 3, 1
VGEN, , P51X, , , , E1_X, E1_Y, E1_Z, , , 1
3D coordinates

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Fig. 3. Parametric definition of the placement of geometry model of the single component of electronic device in 3D space

Listed actions may be independently repeated for each geometry component of the model. Main parameters of each stage may be denoted as: 1) the type of a finite element T (e.g. *SOLID123*); 2) mesh spacing M (e.g. in the range of $0.001 \div 0.1$ mm); 3) mesh spacing manipulation factor F (in the range of $0.5 \div 2.0$); 4) coordinates of interpolation nodes X_n, Y_n, Z_n , where n – node index.

During the parametric definition of initial modeling parameters the following values have to be defined: 1) electrical permittivity of the material of particular component of the device ϵ (or *EPS*, ranges from 1 to several thousand); 2) voltage values of electrodes or other conductive components U (range may vary depending on application); 3) boundary voltage value U_b (typically 0).

The last step includes the analysis (or solution) parameters. The most important of them are: 1) definition of the *FEM* equation solver (in ANSYS: *Direct, PCG, IICG, JCG*); 2) definition of the solution tolerance ($10^{-6}, 10^{-8}, 10^{-10}$); 3) specification of points of interest at which the solution values should be listed; consist of array of point coordinates in 3D space. Number of points usually ranges from one hundred to thousands, so the most practical approach for their selection is the mathematical description of the coordinate mesh consisting of these points [3].

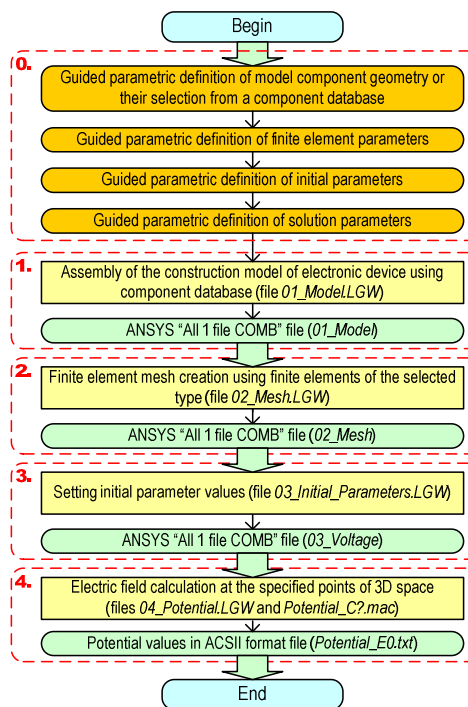


Fig. 4. Simplified modeling algorithm, modified to include the model-driven wizard-based guidance

By using the above-listed principles the algorithm presented in Fig. 1 can be transformed so that the

definition of separate modeling parameters is shifted to the beginning (Fig. 4). For implementing the algorithm, we will create the model-driven wizard.

UML profile for finite element model

The engineering problem of connection between System Engineering and Software Engineering is solved in four main points: 1) creating the UML profile for finite element model; 2) developing a Domain Specific Language (DSL) for user-friendly modeling in that domain; 3) customizing the MD Wizard for guiding the process of specifying an electronic device or a system, and 4) generating a software code.

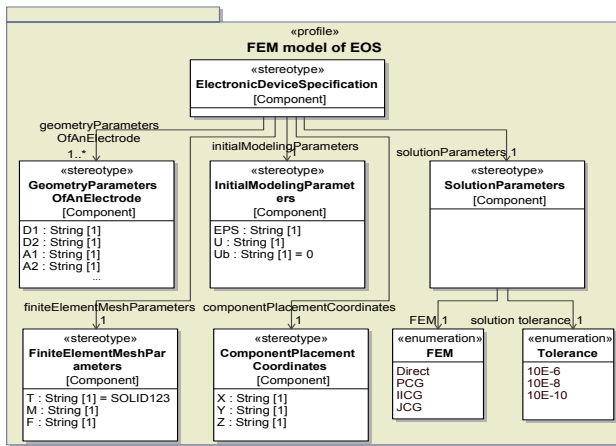


Fig. 5. Profile of FEM model for Electronic Optical Systems (EOS)

UML is the extensible language. It can be extended for usage in custom domain and targeted for custom needs. For building the custom profile based on UML, we need to map the electronic device metamodel to UML metaclasses. The mapping is a non-trivial task because the deep knowledge of how to apply the UML language is needed. Profile for FEM model is presented in Fig. 5.

However, UML specifies no usability features for modeling in a custom domain, that's why tailoring of UML tools for custom needs is needed. In the CASE tool MagicDraw, such a possibility is supported by so called DSL customization [7].

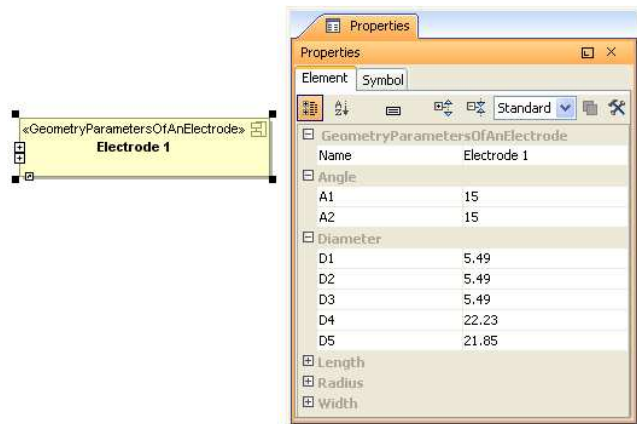


Fig. 6. A custom specification dialog for specification of electrode geometric parameters

DSL customization is defined for each profile element. The example of DSL customization for specifying Electrode geometric parameters is presented in Fig. 6. Here, properties and types of custom domain elements are shown instead of properties and types of standard UML.

After DSL customization, we will prepare the facility for modeling guidance – MD Wizard for supporting the electronic device specification process according to method defined in [8, 9].

Use of model-driven wizard-based guidance

In this section we will use the MD Wizard generation cartridge plug-in in MagicDraw to describe and execute model specification scenario. Scenario consists of 7 main steps: 1) specification of components of electronic device; 2) specification of geometry parameters of an electrode; 3) specification of component placement coordinates; 4) definition of finite element mesh parameters; 5) specification of initial modeling parameters; 6) defining solution parameters; 7) code generation.

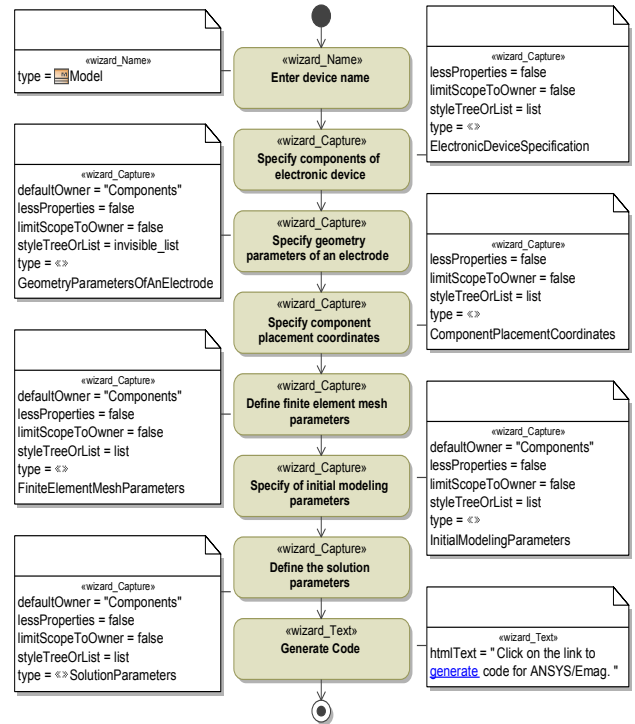


Fig. 7. The MD Wizard-guided process for creating of electronic device model

In Fig. 7 we see an activity diagram representing the electronic device specification workflow prepared for executing it by a wizard. MD Wizard plug-in generates a wizard according to this workflow that guides a user through the process of creating FEM.

The wizard (Fig. 8) output is a model of electronic device, from which further artifacts can be created using standard UML modeling framework (MagicDraw) features: diagrams, documentation, and code. Model of device can be validated for completeness and correctness, transformed, metrics can be calculated.

The last step of the wizard provides a link for generating code from created FEM. This is done by MagicDraw report engine, which generates documents

based on *Velocity Template Language* (VTL). FEM code template explicitly references elements of the electronic device and their properties in VTL specifications.

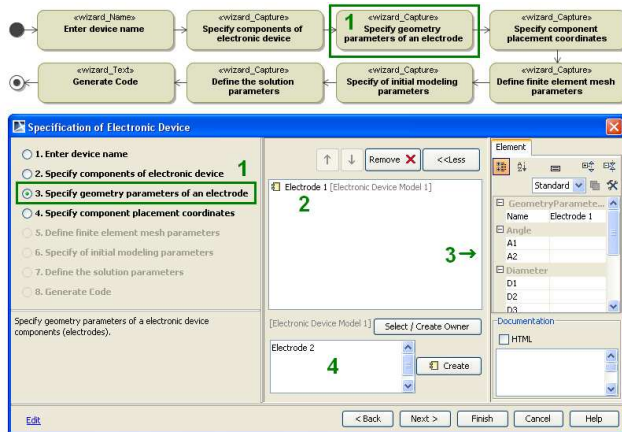


Fig. 8. The step “Specify geometry parameters of an electrode” (1); the specified component (2); the area for specifying the component (3); the area for creating a new component (4)

Report engine enables generating a software code of the desired structure. Also, it supports calculation rules. This allows generated code to be used directly in ANSYS.

From the presented example we can see that the MD Wizard is suitable and flexible enough for supporting the execution of process of engineering an electronic device. However, further improvements would be preferable, for example, a simplified end-user GUI. Another possibility is creating specifications of different components in a single step.

Conclusions

We presented interdisciplinary approach connecting System Engineering (in the field of electronics) and Software Engineering by applying MDE principles for supporting modeling process and generating code. This approach provides a guided way for creating finite element models for fields created by electronic devices. Once created, the model allows using standard features of UML CASE tools, for example, generating the customizable source code. MD Wizard is applied for user guidance in specifying electronic devices and generating source code

for them.

The impact of the proposed approach is multifold: 1) A novel method was presented for applying the MD Wizard for System Engineering; 2) Wizard-based guidance for modeling fields created by electronic devices may potentially reduce the complexity of tasks appointed to the end-user; 3) the time to develop the final product may be effectively reduced. Currently, our efforts are addressed to the extensive practical testing of the proposed approach.

Acknowledgement

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S. Pavalkis, L. Nemuraite, P. Tarvydas, A. Noreika. Specification of Finite Element Model of Electronic Device using Model-driven Wizard-based Guidance // *Electronics and Electrical Engineering*, 2010. – No. 2(98). – P. 59–62.

When modeling the fields of electronic devices the emphasis is given to the improvement of intrinsic features of modeling process itself and continuous simplification of the model building stage. The latter problem is addressed by introducing the idea of wizard-guided specifying the finite element model for electronic devices and generating code for them. Ill. 8, bibl. 9 (in English; summaries in English, Russian and Lithuanian).

C. Павалкис, Л. Немурайте, П. Тарвидас, А. Норейка. Спецификация модели конечных элементов электронного устройства на основе MDE // *Электроника и электротехника*, 2010. – № 2(98). – С. 59–62.

При моделировании полей электронных устройств больше внимания, как правило, возлагается на улучшение самого процесса моделирования и непрерывного упрощения этапа построения модели. Последняя проблема решается путем введения идеи применения MDE руководства для спецификации модели конечных элементов электронного устройства и генерирования кода для нее. Ил. 8, библи. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

S. Pavalkis, L. Nemuraite, P. Tarvydas, A. Noreika. Elektroninio įtaiso baigtinių elementų modelio specifikavimas naudojant MDE pagrindu sukurtą vedlį // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2010. – Nr. 2(98). – P. 59–62.

Modeliuojant elektroninių įtaisų kuriamus laukus, daugiausia dėmesio skiriama modeliavimo procesui tobulinti ir modelio sudarymo etapui supaprastinti. Šiai problemai spręsti iškelta idėja elektroninių įrenginių baigtinių elementų modeliams sudaryti ir kodui generuoti pritaikyti modeliu sukurtą vedlį. Il. 8, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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