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SENSOR SPECIFICATION USING THE ISA AND STEP STANDARDS FOR SENSOR SELECTION

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Abstract - In this paper, a framework is proposed for computer supported sensor selection and design. An important requirement to this is that the specifications of sensors can be matched with requirements. Therefore sensors and requirements must be specified unambiguously. It is foreseen that a software system for this will have to acquire information from suppliers automatically, in order to stay up to date. Also different parts of the software system will have to exchange information. We conclude that a standard neutral information exchange format for the specification of sensors is desired.

In this paper an overview of the problem is given. STEP and PLib are introduced as standards for information exchange about products and parts respectively. However, the field of sensor specification has not been developed yet and it is proposed in this paper to do this.

As an example, sensor specification within the class of strain gage transducers is worked out. First an overview of modelling options is discussed and then it is demonstrated how sensor specifications might look in the PLib format. It is concluded that the PLib standard is indeed suited for exchanging specification information about sensors.

Keywords: sensor selection, measurement system design, design automation

1. INTRODUCTION

This paper addresses computer-supported sensor selection to assist the design of automated systems. There are a number of reasons for introducing computer support in this field. In the first place, these days no designer can have a complete overview of all available measurement principles used for existing sensors so that computer support for finding one will be welcome. In the second place, the computer can assist in making an optimal choice based on criteria and requirements from the designer and on sensor specifications provided by the sensor supplier. Note that criteria may be technical but also economical.

The final aim of our activities is to create a software system, to assist the designer while choosing sensors. In this paper we describe a framework for such a system. It appears that much information exchange is necessary, between the system and the outside world as well as between system components. Therefore we concentrate on methods to standardise sensor specification in a neutral data format.

In the remainder of the paper, an inventory of the necessary elements of the software system will be given together with an example: Designing a force sensor based on an elastic element and strain gages. Section 2 contains the architecture of a sensor selection and design system. In section 3 models are introduced describing force sensors using strain gages as transducer. Section 4 considers two standardised information exchange protocols: the STandard for the Exchange of Product model data (STEP) and PLib (Parts Library), which is derived from it. In section 5, some elements of the optimisation of the sensor choice are discussed. To conclude, in section 6 conclusions are drawn.

2. ARCHITECTURE OF A SENSOR SELECTION SYSTEM

Considered from the viewpoint of a system designer, sensor design and selection are related fields. During a design, a system is iteratively divided into smaller parts until parts occur that can be bought from suppliers. In many cases, the designer has the choice between buying a part from the shelf and assembling it from smaller parts. This illustrates the relation between (sensor) selection and design.

Figure 1 shows a scheme of a selection/design system, which has been worked out in [2]. According to this scheme there are in general two stages. First a measurement principle is selected and then during a second stage, one or more sensors are chosen from a supplier's guide.

Finding a measurement principle means to find transducers that can transform the input measurand to a quantity in the electrical domain. In [2] it is proposed to describe this transformation as an energy (or power) transformation, where the energy domains are separated by a two-port, which performs the transformation. Possibly more than one transformation can be implemented containing

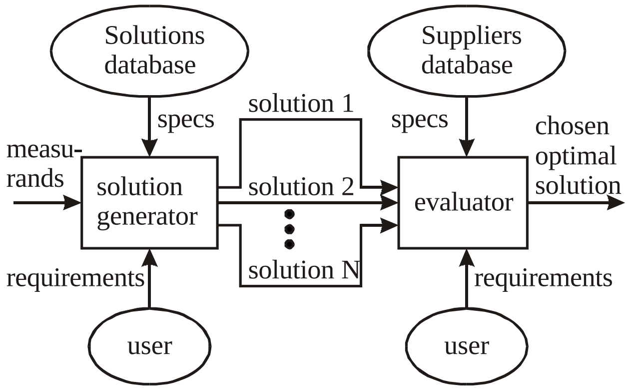


Figure 1 Architecture of a sensor selection/design system

intermediate energy domains.

In figure 1, the solutions generator generates a measurement solution, which is a chain of transformations that transform the input quantity (the measurand) to an electrical output quantity. The solutions database contains a set of objects that can implement a certain transformation. The generator will only propose a certain transformation if the solutions database contains an object that implements it.

The solutions database only contains classes of solutions based on categories of transducers with global specifications. The suppliers database will contain explicit catalogues of specified sensors including information on dimensions and costs.

As can be observed, a sensor selection/design system contains a number of subsystems, which have to be interfaced. In this paper, the option will be considered to bring all information crossing an interface into standard form according to ISO standards and the STEP data-exchange format.

3. DESIGNING/SELECTING FORCE TRANSDUCERS

3.1 Sensitivity of the force transducers

The class of force sensors that we will consider consists of an elastic element, which deforms because of the applied force. The deformation is expressed in terms of the strain, which can be measured in a number of ways. Thus when designing a force sensor, an elastic element must be selected together with a method to measure its strain. With respect to the strain measurement we will restrict ourselves to the use of strain gages, brought together into a Wheatstone bridge circuit, see figure 2.

The mechanical sensitivity of the elastic element can be

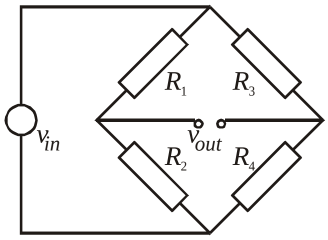


Figure 2 Strain gages R_1 to R_4 in a Wheatstone bridge circuit

defined as the strain e per unit of exerted force F:

$$S_m = \frac{\partial e(F)}{\partial F} \qquad (1)$$

The electrical sensitivity is the relative voltage change from the Wheatstone bridge per unit of strain:

$$S_e = \frac{\partial\left(v_{out}(e)/v_{in}\right)}{\partial e} \qquad (2)$$

where v_{in} is the input voltage to the Wheatstone bridge and v_{out} is its output voltage.

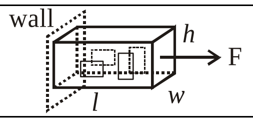
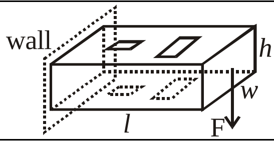
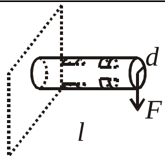
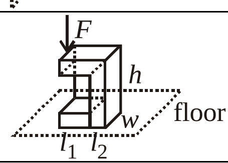
The electrical sensitivity depends on the way the strain gages are connected to the elastic element. Depending on the shape of the element and the strain gage configuration, sensitivities between 2 and 4 are obtained.

Together the mechanical and the electrical sensitivity determine the overall sensitivity of the force transducer:

$$S = \frac{\partial(v_{out}(F)/v_{in})}{\partial F} = S_m S_e \qquad (3)$$

It is this overall sensitivity that we would like to optimise during the design of a force transducer.

Table 1 Simple elastic element geometries with some properties

Type	Force range [N]	Mechanical Sensitivity [µm/(Nm)][1]	Sketch of the shape
Stretched/ compressed column	10^1-10^7	$\frac{1}{Ewh}$	
Bent lamella (cantilever beam)	10^{-2}-5.10^4	$\frac{6l}{Eah^2}$	
Bent and/or twisted shaft	10^0-10^5	$\frac{32l}{p\,Ed^2}$	
Bent yoke	5.10^0-5.10^4	$\frac{6l_1/l_2 - 1}{Ewl_2}$	

[1] E is the elasticity modulus, which depends on the material of the elastic element

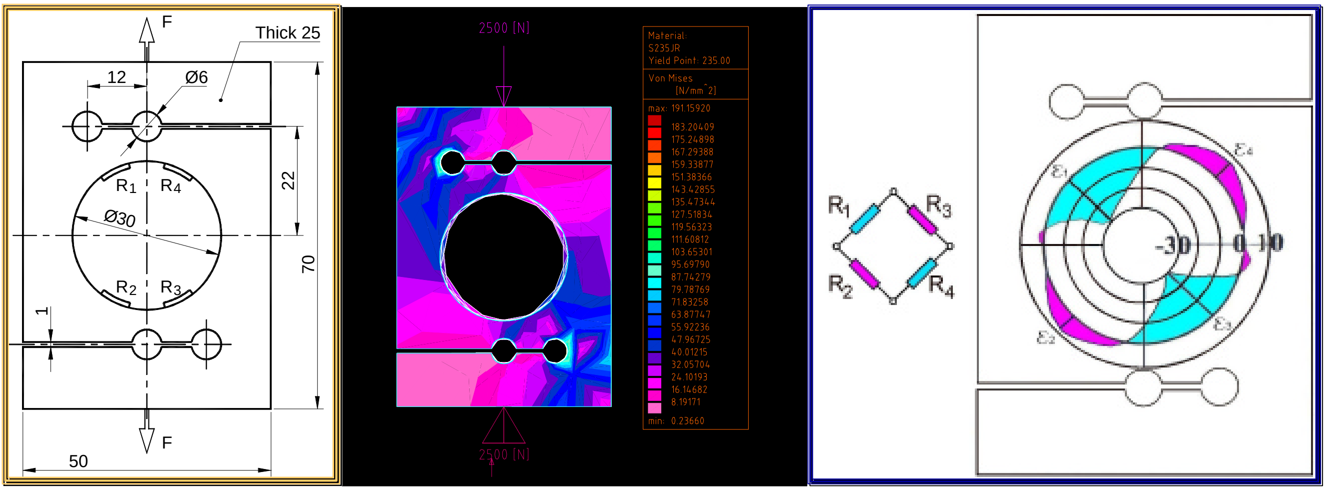


Figure 3 Elastic element, left: design, middle: computed stress pattern, right: computed strain pattern along the central hole

3.2 Computation of the mechanical sensitivities

To compute the sensitivities there are two options:

Option 1 – Simple shapes

For simple shapes the strain and the mechanical and electrical sensitivities can be computed analytically. A number of geometries are given in table 1, more of them are discussed in [5].

Option 2 – Using numerical procedures it is possible to compute the strain as a function of the applied force and from that the sensitivities S can be computed. The idea of this paper is therefore to prepare a set of predefined shapes, to compute for each shape the relation between the force and the strain and to choose a measurement location for the strain, to optimise the overall sensitivity.

Consider as an example the elastic element, sketched in figure 3 left. It consists of a block in which one big hole and four smaller ones have been drilled. Figure 3, middle, shows a graphical representation of the occurring stresses all over the block, while figure 3, right, shows the strain around the boundaries of the big hole. The applied force was 2500N. The shape of this elastic element can be tabulated together with the maximum sensitivity. Doing this for a number of shapes results in a library of shapes together with their sensitivities. Other properties like size and force range will have to be added to enable a good choice.

4. SENSOR SPECIFICATION ACCORDING TO STEP AND PLIB

4.1 Introduction

A support system for sensor selection will have to communicate extensively with the outside world, especially to obtain sensor data from suppliers. To use supplier data on a large scale, data acquisition will have to be carried out automatically. In the Computer Aided Design world, STEP (the STandard for the Exchange of Product model data, ISO-10303) [1] is coming up as software standard for exchanging product information between heterogeneous computer systems. STEP has been designed such that products can be described from many viewpoints. One viewpoint is the physical geometry of a product. Other viewpoints are its performance and its costs.

Models are coded in a high-level language EXPRESS. EXPRESS cannot be used directly in a computer program: There are no EXPRESS compilers. Instead, using a *binding*, the models are translated to data structures in a computer language, like C++ or JAVA. Following this way, an application (e.g. a sensor selection program) can be developed, without dependence on other applications from which it will obtain information, like the electronic catalogue of a supplier. Of course, a requirement to the supplier will be, to follow the STEP standards.

Example of the use of EXPRESS

```
SCHEMA example1;

ENTITY part;
    name            : string;
    part_number     : INTEGER;
END_ENTITY;

END_SCHEMA;
```

Given this schema, an *instantiation* of such a part is:

```
#1 = part("elastic element", 25);
```

STEP is an extremely large framework of standards that have been defined in words, but finally have been written in the form of EXPRESS schemas so that they are computer interpretable. It is almost never necessary to write new schemas, unless one is involved in the development of a completely new area.

While STEP itself concentrates on products as a whole, PLib (parts library, ISO-13584) [3] has been developed according to STEP-rules, while it is dedicated to parts and components, which should be assembled to a product. It is a neutral data exchange format, meant to be used for electronic catalogues of parts suppliers. In our view it is also valuable as a data exchange format within an information system, which then can be assembled from heterogeneous parts, like a CAD-system and an optimisation system.

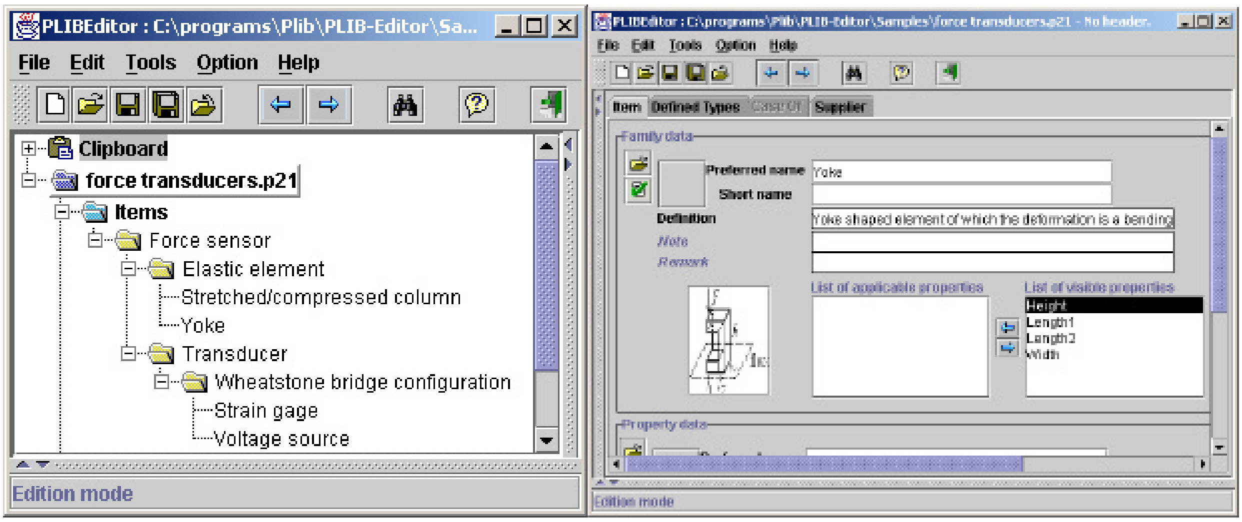


Figure 5 Left: tree structure with the dictionary of a force sensor; Right: Description of the element Yoke

4.2 Organisation of PLib

PLib consists of an information model prescribing how to describe parts in general. The model has been defined in the form of a large number of EXPRESS schemas.

Thus to describe a family of parts with PLib, one only has to create instantiations using the PLib schemas already defined in EXPRESS. These instantiations together form a *dictionary* in which the concepts of the sensor description are laid down. To conclude, a *library* of parts is compiled by filling in explicit parameter values kept unspecified in the dictionary.

The handles around which a dictionary is organised is the Basic Semantic Unit (BSU). Each concept (element or property) is identified using a BSU. The dictionary is obtained by defining relations between the BSUs.

4.3 Specifying force transducers

To illustrate the use of PLib for part specification, we consider the case of the class of force transducers

A simple example has been worked out using a program called *PLib Editor* [4]. Figure 5 left shows a tree reflecting the dictionary with a simplified concept of a force transducer. The definitions of the properties of the Yoke-element are shown in the right part of the figure. After finishing the description, the user can save it in the form of a PLib-compliant file.

The underlying model of a yoke is sketched in table 1. Its PLib implementation is depicted in figure 4. "Identification properties" are shown horizontally. Vertically, relations between the yoke and its geometrical parameters are shown. We note the following points:

- The hierarchy in the tree structure of figure 5 is brought into PLib by defining relations between different class BSUs (e.g. the "name scope" relation between the Yoke class and its properties and "part of" relation between the Elastic Element-class and the Yoke class.
- Relations between properties can be expressed in the form of tables or in the form of mathematical formulae. So the dependence between the mechanical sensitivity of the yoke and its geometrical parameters:

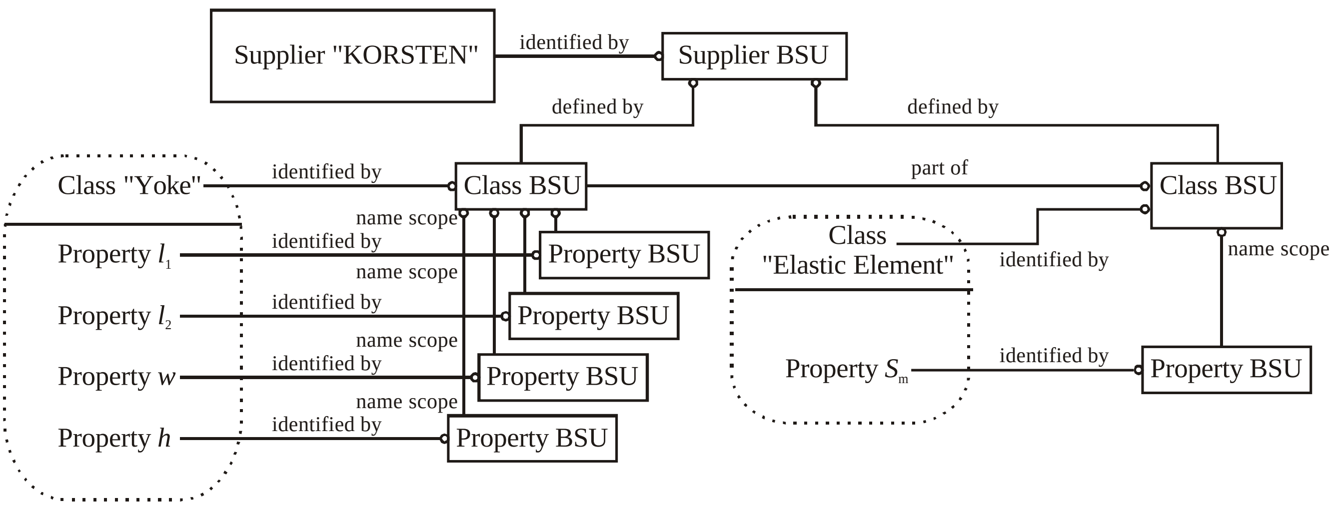


Figure 4 Pictorial representation of the dictionary of the yoke element. Horizontally: identification properties (except "part of"). Vertically: relations between different BSUs

$$S_m = \frac{6l_1 / l_2 - 1}{Ewl_2}$$

can be coded into a PLib-dictionary.

- STEP and PLib are designed to enable different views of objects or components. Thus a strain gage has mechanical properties like its physical dimensions, but also electrical properties so that it can be brought into an electrical circuit (Wheatstone bridge).

At the moment extensive PLib-dictionaries exist, describing the geometric properties of objects. Therefore sensor shapes can be designed using programs like "Mechanical Desktop", which easily can generate geometric STEP-files of the design. However to the knowledge of the authors, no such dictionaries seem to exist describing the functional properties and specifications of sensors. This work has still to be done.

5. OPTIMISATION OF THE SENSOR SELECTION

The choice between solutions means comparing specifications of different sensors with each other, but also to weigh the various criteria, as accuracy and costs. Thus the user should give requirements on different specification fields, including admissible ranges, and indicate how important they are. A complication arises if not all specifications of a sensor are available. Multi Criteria Decision Making (MCDM) [7] has been described in the literature. The values and the importance of a requirement will have to be expressed in terms, linking up with the way of thinking of the user. Thus expressions like "very important", "not so important", "absolutely necessary" may be more appropriate than numbers like 0.7. Therefore the use of fuzzy criteria may be a good proposition [7].

6. CONCLUSIONS

Computer support during system design enables the designer to use information from all over the world effectively. However to make this information valuable, its interpretation should be unambiguous making standardisation inevitable. We propose to set up a system for computer support for the selection process of sensors, using the ISA, STEP and PLIB standards.

In this paper we have concentrated on the PLib standard to show that it can be used as a neutral data format for exchanging specification information about sensors. The next step will be to assemble a sensor selection and optimisation system as much as possible from existing parts.

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