ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1992
Seria: MECHANIKA z. 108 Nr kol. 1161

International Conference on
COMPUTER INTEGRATED MANUFACTURING
Internationale Konferenz über
RECHNERINTEGRIERTE FERTIGUNGSSYSTEME
Zakopane, March 24-27 1992

WIESŁAW TARELKO

Department of Machine Design
Merchant Marine Academy,Gdynia,Poland

EXPERT SYSTEM FOR MAINTAINABILITY DESIGN

Summary. The paper considers method by which professional desingers can beneficially influence ship equipment maintainability. It is proposed that maintainability be treated as a design variable and incorporated into design process. Design method is described basing on knowledge engineering methodolgy, by which qualitative maintainability characteristics may be "builit" into design using production rules.

1. Introduction

The paper is concerned with the investigation of expert system techniques for the maintainabality design of ship equipment. It is important that the procedures used by such expert system to manipulate models and their attributes are formulated in terms of a set individual functions which a desinger can cause to be executed on the computer. Only in such circumstances will one be able to formulate any high-level machine-based procedure which would " explain " its actions. For the same reason the procedures used by the machine must be coherent with the principles in terms of which the man thinks about the tasks which are being carried out. In order to achieve these key attributes of referential transparency and coherence, the maintainability design techniques presented here are based on a systematic approach to designing for maitainability. The basic problem of maintainability design is to create a system so that a specified set of attributes.

2. Systematic approach to maintainability design

The maintainability concept is concerned with characteristics of design , manufacture and instalation which affect the ability of the item (sub-system , equipment or part) to be retained in or restored to service by means of maintenance actions which are performed by qualified service personnel using established procedures, resources and tools, at the item's prescribed level.

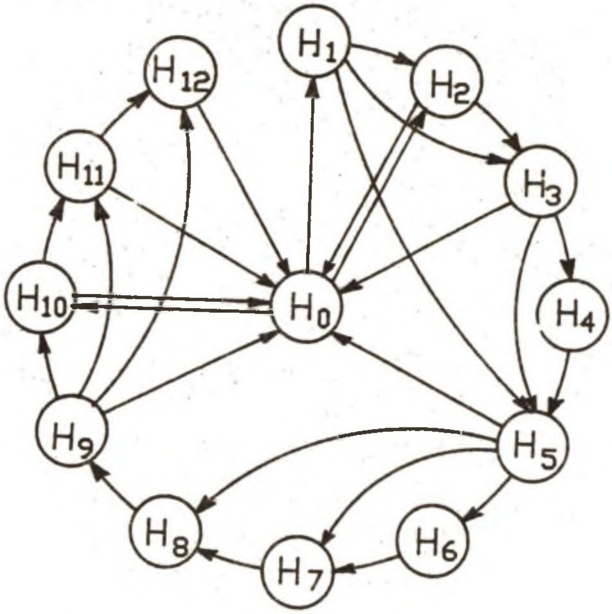

Fig.1.A graph of the maintenance process

It is useful to think upon maintainability as a design variable in the same manner as stress, power, etc. Maintainability falls into class of dependent design variables, as understood by design engineers. It comes into existence by selecting the constructional features. We can consider the control of maintainability level as a process of selecting constructional features to conform system to some specified requirements. Then, maintainability as characterisic of system can be described by means of a set of constructional maintainability factors. If we want to influence on maintainability we should know the mentioned set. This set we can obtain considering maintainability as a complexity feature of system which may be decomposed into simple parts. Let us consider process of maintenace actions as sequence of the following stages (fig.1.):

- H_0 - operational use,
- H_1 - waiting for maintenance action,
- H_2 - failure detection,

- H_3 – localization of cause,
- H_4 – technical delays (setting time, cooling, etc.),
- H_5 – disassembly,
- H_6 – waiting for spare parts,
- H_7 – regeneration of damaged parts,
- H_8 – interchange,
- H_9 – reassembly,
- H_{10} – adjustment,
- H_{11} – final check,
- H_{12} – waiting for operational use.

According to the kind and range of a damage the system can be found in different stages. The time of staying in one of them depends mainly on the following constructional maintainabality characteristics:
- accesibility,
- ergonomic factors,
- interchangeability and normalization parts,
- automation and mechanization of maintenace actions.

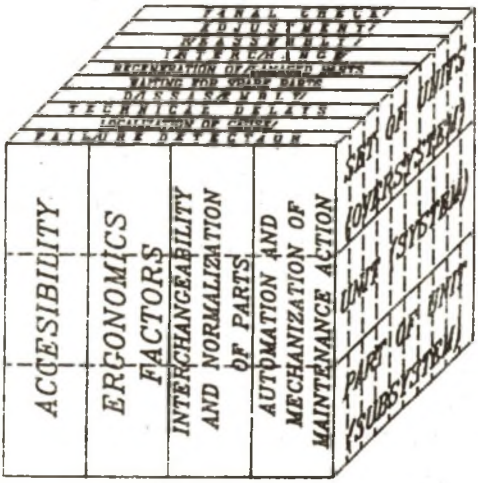

Fig.2. A structure of relationship between terms

The mentioned characteristics can be considered for various hierarchical levels of system , namely:
- a set of units, that is oversystem,
- an unit, that is system,
- a part of unit, that is subsystem.

All considered elements that is:
- stages of process of maintenance actions,
- constructional maintainability characteristics,
- levels of a system,

create several related terms. Figure 2 shows a structure of relationship between ones . It is collection of simple cubes. To each of them we can attribute simple characteristics of maintainability like:
- accesibility to unit during failure detection,
- interchangeability and normalization of parts during interchange, so on.

Because the process of maintainability design is realized in the fact of selecting the constructional features, therefore we can attribute the set of constructional maintainability factors to each simple maintainability characteristic. The space of its kind of possible solutions for the mentioned set is created by the collection of these cubes. This space allows us to specify a large number of construtional maintainability factors which can realize simple maintainability characteristics.

3.<u>Structure of expert system</u>

The achievment of good maintainability through design involves all aspects of design ability. Desingers should accept a commitment to consider at all stages in the design process. This involves facing the challenge of handling, in a qualitative manner, a design variable which can be subjective by nature when undertaking design exercises.
Expert system method based on knowledge engineering methodology may be used to good effect in this respect.
The principle of action that expert system consists in offering to the desinger some principles of constructional solutions in the following forms:
- rules in the classical concept of expert system,
- graphic interpretation of these rules.

In our approach to representing maintainability design knowledge, a frame-based representation is adopted. Frames unify both the procedural and declarative expression of knowledge. A frame is a generic data structure containing any desired number of categories of information called slots, where this information is associated with the subject of the frame.
The frames have three basic types of slots:
- attribute slots,
- procedure slots,
- connection slots.

The attribute slots relate to the declarative part of the frame knowledge. They describe the information represented in the frame. The type and number of frame attributes will depend on the domain whose knowledge is being represented.
The procedure slots define how the information required by the frame should be obtained and what actions should be taken if the desinger selects that frame.
The connection slot defines the position of the current frame

within the knowledge base.
The frames can have common slots. It is the main advantage of our approach to representing maintainability design knowledge because we can join the information which we have obtained from different points of view.

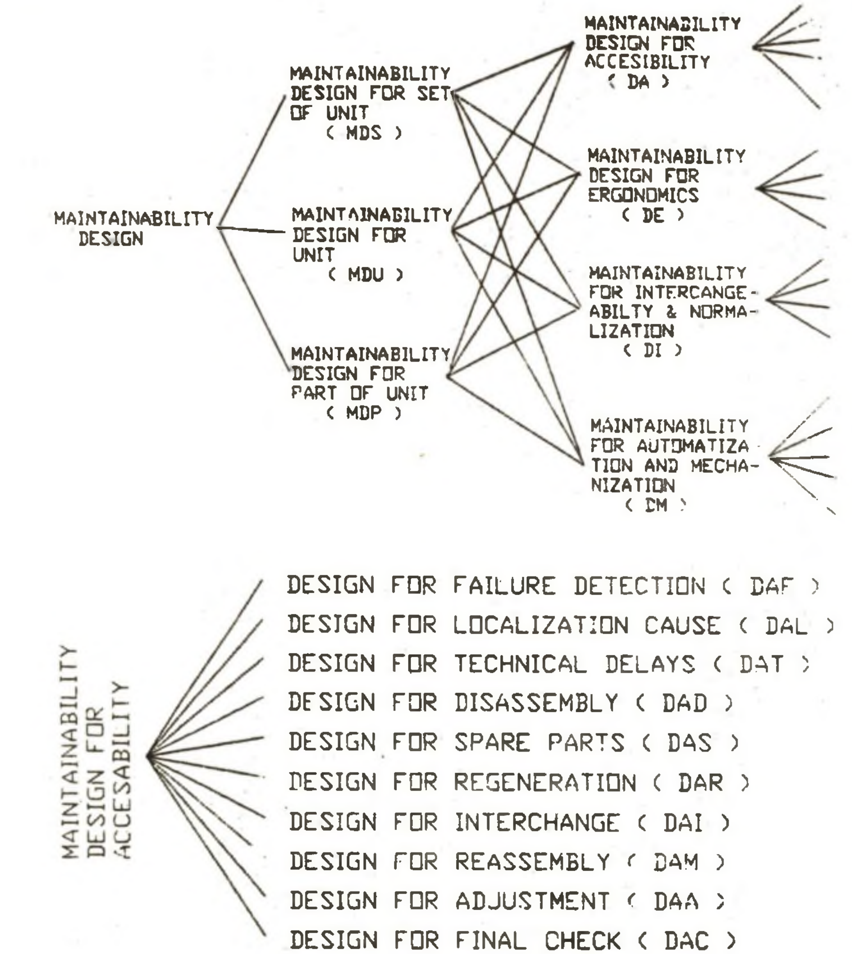

Fig.3. A structure of the knowledge base

4. Development of expert system

According to systematic approach our design problem has been divided into a number of sub-problems.

First we divide the design method into three techniques which represent three levels of complexity that is:

- oversystem (maintainabilty design for a set of units)-MDS
- system (maintainabilty design for unit)-MDU,
- subsystem (maintainabilty design for part of unit)-MDP.

Secondly we break down the design into four separate parts according to four main characteristics of maintainability:

- design for accesability -DA,
- design for ergonomics -DE,
- design for interchangeabilty and normalization of parts -DI,
- design for automatization and mechanization of maintenance actions -DE.

Finnally, we divide the design into ten separate sections in accordance with stages of maintenance process.
Figure 3 summarized the systematic approach and shows how the design techniques are organised into a hierarchy. The systematic nature of the design techniques facilites the development expert system. Design rules have been specificially developed in conjuction with development of each technique. For example, as the maintainability design has been

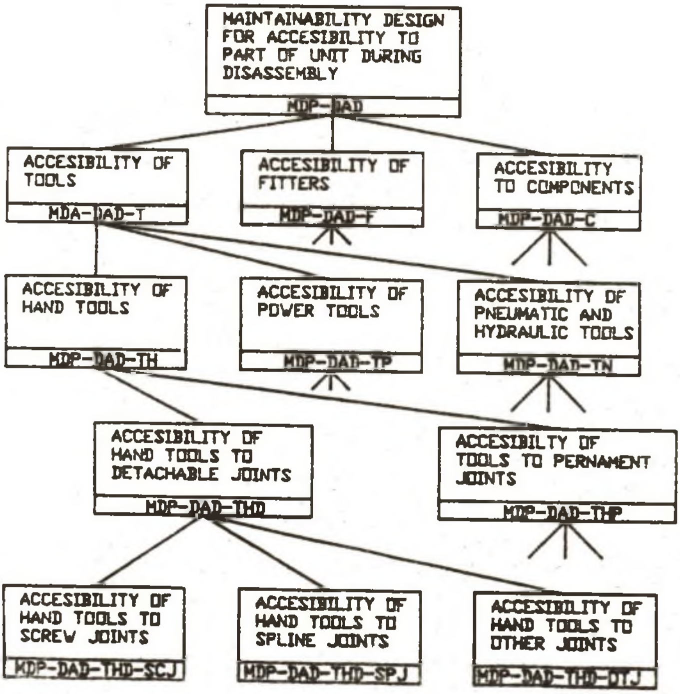

Fig.4. A hierarchy structure of module

FRAME - NAME	: ACCESABILITY TO PART OF UNIT DURING DISASSEMBLY FOR HAND TOOLS OF SCREW JOINTS (MDP-DAD-THD-SCJ)
CONNECTION SLOT	
A kind of (AKO)	: MDP-DAD-THD
Instance	: ————————
ATTRIBUTE SLOTS	
Design attribute	: B1 - (H=150 mm, W=135 mm) & draw.1
	: B2 - (H=200 mm, W=265 mm) & draw.2
	: B3 - (H=180 mm, W=195 mm) & draw.3
	: B4 - (H=135 mm, W=170 mm) & draw.4
	: B5 - (H=150 mm, W=135 mm, D=210 mm) & draw.5
	: B6 - (H=160 mm, W=125 mm, D=210 mm) & draw.6
	: B7 - (H=180 mm, W=195 mm, D=210 mm) & draw.5
	: B8 - (H=210 mm, W=115 mm, D=130 mm) & draw.7
	: B9 - (H=145 mm, W=135 mm, D=210 mm) & draw.5
	: B10 -(H=155 mm, W=115 mm, D=210 mm) & draw.8
	: B11 = B5
	: B12 = B8
Evidence attribute	: A1 - On the outside face of the exit canal the joint is situated
	: A2 - In the inside space of the vertical exit canal the joint is situated
	: A3 - In the inside space of the horizontal exit canal the joint is situated
	: A4 - Use of a screwdriver
	: A5 - Use of a flat (box) wrench
	: A6 - Use of a socket wrench or obsruction spanner
	: A7 - Use of a pliers
Concept attribute	: To design space required for using common hand tools of screw joints
PROCEDURE SLOTS	
Control slot	: A1 > A4 > A5 > A6 > A7 or
	A2 > A4 > A5 > A6 > A7 or
	A3 > A4 > A5 > A6 > A7
Rule slot	: IF (A1) IS (YES) & A4 IS (YES) THEN B1
	: IF (A1) IS (YES) & A5 IS (YES) THEN B2
	: IF (A1) IS (YES) & A6 IS (YES) THEN B3
	: IF (A1) IS (YES) & A7 IS (YES) THEN B4
	: IF (A2) IS (YES) & A4 IS (YES) THEN B5
	: IF (A2) IS (YES) & A5 IS (YES) THEN B6
	: IF (A2) IS (YES) & A6 IS (YES) THEN B7
	: IF (A2) IS (YES) & A7 IS (YES) THEN B8
	: IF (A3) IS (YES) & A4 IS (YES) THEN B9
	: IF (A3) IS (YES) & A5 IS (YES) THEN B10
	: IF (A3) IS (YES) & A6 IS (YES) THEN B11
	: IF (A3) IS (YES) & A7 IS (YES) THEN B12
	: IF (A4) IS (NO) & (A5) IS (NO) & (A6) IS (NO) & (A7) IS (NO) THEN EXIT SLOT IS CONNECTION SLOT of MDP - DAD - THD
Exit slot	: Connection slot of MDA - DAD

Fig.5 A structure of the frame

broken down into separate sections in accordance with stages of maintenance process, rules for dealing with each stage are developed. As a result we have a knowledge base which has a set of modules of maintainability techniques. It stands to

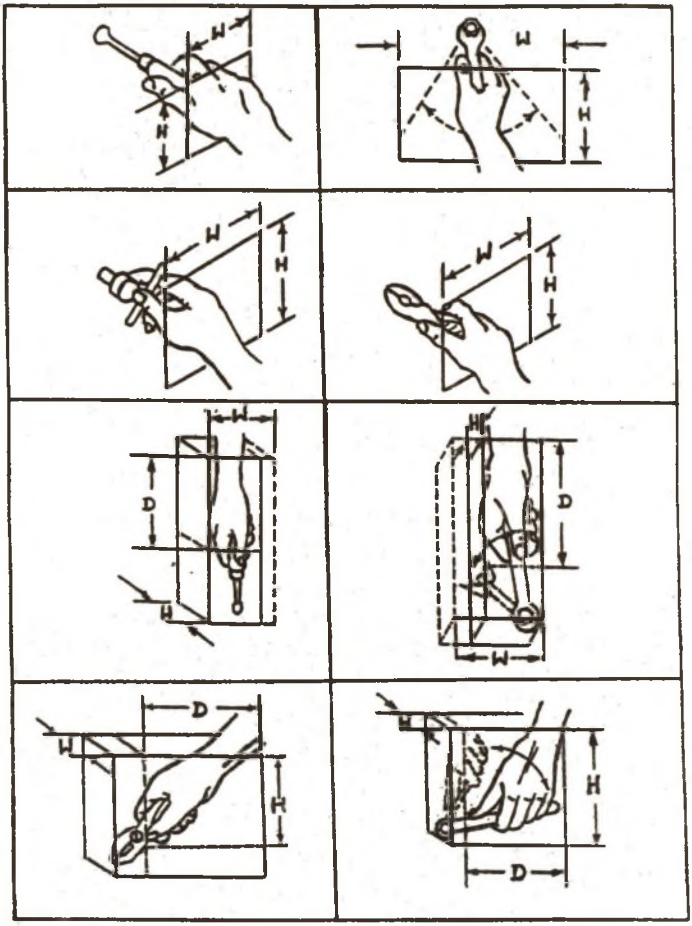

Fig.6. Drawings of the design attributes

reason that a range of the maintainability design knowledge of each module may be different. That domain knowledge can have a good described design principles, for instance of module "Maintainability design for accesability to parts of unit during disassembly". On the other hand, there can exist a visible lack of that knowledge, for example of module "Maintainability design for ergonomics to parts of unit during localization cause". In the first case this involves next decomposition of design problems.

Finnally we obtain a knowledge base which is extremely modular and the rule bases can be written debugged and updated separately. A hierarchy structure of module "Maintainability design for accesability to parts of unit during disassembly" is shown in figure 4. Each object in the knowledge base is a frame.
For instance, figure 5 shows a frame "Accesability of hands tools to screw joints". The design attributes of that frame consists of dimension of exit canals required for using common tools of screw joints. The first of three of evidence attributes show the kind of a face and a space of exit canals, the rest of them , kind of common tools. The design attributes are complementary by drawings which are shown in figure 6. The systematic nature of the design maintainability techiques facilitated the formal development of the production rules. Each rule denoted a simple design event and was shown of the form :

IF (conditions) THEN (consequents).

The rules were grouped into modules which formed in accordance with the maintainability design techniques. The design method which is based on the use of these production rules, is simple and systematic.

EIN BERATUNGSSYSTEM FÜR REPERATIONSFÄHIGKEITSPROJEKTIERUNG

Zusammenfassung

In der Arbeit wurde eine Projektierungsmethode dargestellt, mit welcher die Entwurfsingenieure auf die Reperationsfähigkeit des Projektionsobiektes einen Einfluss geltend machen können. Die vorgeschlagene Methode nutzt die Methodologie der Wissenschaftsingenieurstechnik zum Bau eines Beratungssystems für Reperationstechnik von Maschinen und Schiffseinrichtungen aus. Diese Methode gestttet eine Einführung in den Entwurf von qualitativen Konstruktionsfaktoren, welche einen grundsätzlichen Einfluss auf die Reperationsfähigkeit der Einrichtung ausüben.

SYSTEM DORADCZY PROJEKTOWANIA NAPRAWIALNOŚCI

Streszczenie

W pracy przedstawiono metodę projektowania,za pomocą której projektanci mogą oddziaływać na naprawialność projektowanego obiektu. Proponowana metoda wykorzystuje metodologię inżynierii wiedzy do budowy systemu doradczego projektowania naprawialności maszyn i urządzeń okrętowych. Pozwala ona wprowadzać do projektu jakościowe czynniki konstrukcyjne mające istotny wpływ na naprawialność urządzenia.

Wpłynęło do redakcji w styczniu 1992 r. Recenzent: Wojciech Cholewa