New Intelligent Interactive Automated Systems for Design of Machine Elements and Assemblies

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Abstract. This paper presents a new concept of intelligent interactive automated systems for design of machine elements and assemblies on the basis of its features described in a natural language. In the proposed system, computational intelligence methods allow for communication by speech and handwriting, meaning analyses of design engineer's messages, analyses of constructions, encoding and assessments of constructions, CAD system controlling and visualizations. The system uses an intelligent subsystem for assessment of engineer's ability for efficient designing. It is capable of control, supervision and optimization of the designing process. The system consists of spoken natural language and handwriting interfaces between the designing system and design engineers. They are equipped with several adaptive intelligent layers for human biometric identification, recognition of speech and handwriting, recognition of words, analyses and recognition of messages, meaning analyses of messages, and assessments of human reactions. The paper also makes a comparison of the proposed new automated designing system with the present system of realization of designing tasks. In the system also proposed are new concepts of a system of symbolic notation of construction features and language for notation, archiving and processing of construction description data (object oriented language for construction).

Keywords: Artificial Intelligence, User-Computer Interaction, Intelligent Designing System, Intelligent Interface, Natural Language Processing.

1 Introduction

The presented research involves the development of complex fundamentals of building new intelligent interactive systems for design of machine elements and assemblies on the basis of its features described in a natural language. The scientific aim of the research is to develop the bases of new design processes featuring the higher level of automation, objectual approach to problems and application of voice communication between design engineers and the data processing system. The comparison of the proposed new automated designing system with the present system of realization of designing tasks presents (fig. 1).

The design and implementation of intelligent interactive automated systems for design is an important field of research. In these systems, a natural language interface using speech and handwriting is ideal because it is the most natural, flexible, efficient, and economical form of human communication [1-3]. This concept proposes a novel approach to intelligent interactive automated systems for design of machine elements and assemblies, with particular emphasis on their ability to be truly flexible, adaptive, human error-tolerant, and supportive both of design engineers and intelligent agents.
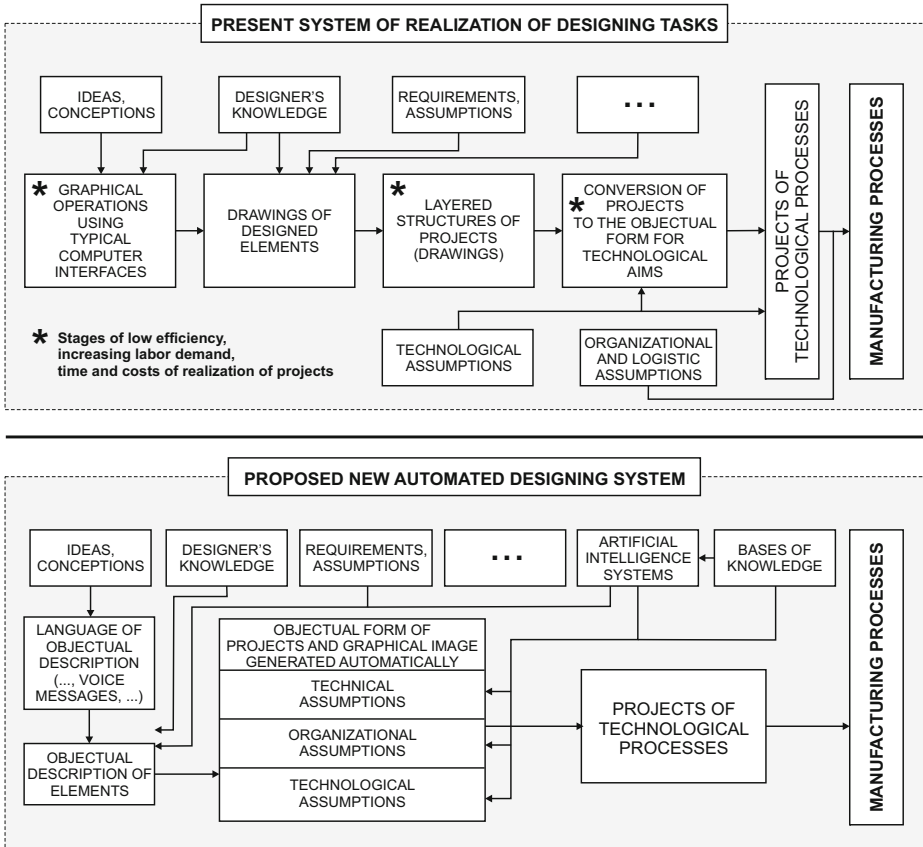
Fig. 1. The comparison of the proposed new automated designing system with the present system of realization of designing tasks

Application of intelligent interactive systems for design machine elements and assemblies using a natural language offers many advantages. It ensures robustness against design engineer errors and efficient supervision of machine design processes with adjustable level of automated supervision. Natural language interfaces also improve the cooperation between a design engineer and a design

system in respect to the richness of communication. Further, intelligent inter-action allows for higher organization level of complex design processes, which is significant for their creativeness and efficiency. Design process decision and optimization systems can be remote elements of design processes.

The design of that intelligent system can be considered as an attempt to create a standard intelligent interactive automated system for design processes using natural language communication. It is very significant for the development of new effective and flexible designing methods. It can also contribute for increase of efficiency and decrease of costs of designing processes. This designing system provides an innovative solution allowing for more complete advantages of modern manufacturing processes nowadays.

At the Koszalin University of Technology, taking advantage of the own developed solutions in the range of voice communication between users and technical devices, with the use of artificial intelligence, the research went on to be carried out concerning the development of complex fundamentals of building new intelligent interactive systems for design of machine elements and assemblies on the basis of its features described in a natural language.

2 The State of the Art

The most important disadvantages of the present systems for creating construction notation can include:

1. Creation of constructions through executions of graphical operations, with the use of slow communication interfaces, in the form of a keyboard, tablet and mouse, on elementary components of the types of lines and graphic symbols.
2. Drawing is still excessively taking part in imposing the engineer designer's thinking processes.
3. Completing and processing of data occurs in layers, which contain graphical symbols of particular types. Because of that fact, it is difficult to take advantages of objectual treatment of geometrical components of a particular object, e.g. particular grade of designed shaft or even particular cutting.
4. Completing and processing of data in layers containing graphical symbols of particular types (lines, circles,) causes that the software for technological process design has to perform operations of recognition of elementary graphical objects basing on analyses of graphical notation of these elements (reconstruction of drawings in the technological aspect).
5. Storing information of graphical image instead of storing information in the objectual form of elementary object components and relations between them.
6. Storing construction description data in typical formats for older vector graphic systems using elementary drawing components (lines) instead of using objects which will draw themselves as the result of code interpreter operations.

7. The last disadvantage can be clarified through a comparison of different description methods: construction drawings and description methods of document structures (XML) and internet pages (HTML). From this comparison we can find out that instead of storing a vector drawing, object features can be recorded and the interpreter recreates the drawing on any operating system with the use of universal software. After changing the object features, this drawing will be recorded as a set of features again.

It is worth to notice that the proposed solutions of object feature notation allow for arbitrary advancement of notation integration of construction features and technological process features, and also organizational instructions. It ought to be admitted that remain such cases for which the verbal or symbolic description would not be unequivocal enough [1]. Then data in the graphical form will play an important role. The supplementary information will also provide data from reconstruction processes of shapes and dimensions in the graphical and numerical form.

In the complex design tasks, the release of designer engineers from manual usage of slow interfaces, will allow for elimination of an indirect phase (composing of drawings from graphical symbols). The phase degrades objectual perception of designed object elements to the layered and fault level for further project usage. The application of intelligent interaction systems aims at increase of the designers' efficiency and convenience, and rapidity of creation of new constructions.

The current research has focused on the addition of a supplement to CAD systems [4,5], which consists of simple mechanisms of providing information in the vocal form (in a form of a simple interface for recognition of selected elementary shapes). In that work the objective was to simply support the tasks in traditional systems (simple interface for selective control of a CAD system) [5].

3   Description of the System

The new concept of intelligent interactive automated systems for design of machine elements and assemblies is presented in abbreviated form on Fig. 2. The intelligent designing system is equipped with a subsystem for intelligent assessment of design engineer's ability for efficient designing. The numbers in the cycle represent the successive phases of information processing. The system performs biometric identification of the design engineer whose spoken messages in a natural language are converted to text and numeric values. The recognized text is processed by the meaning analysis subsystem performing recognition of words and messages. The results from that natural language interface are recognized meaningful messages with essential information, which are sent to the subsystem of construction analyses. The analyzed constructions are processed by the subsystem of construction encoding. The novel language for construction notation is used for encoding of the constructions. The next phase of the processing is in the subsystem of construction assessment.
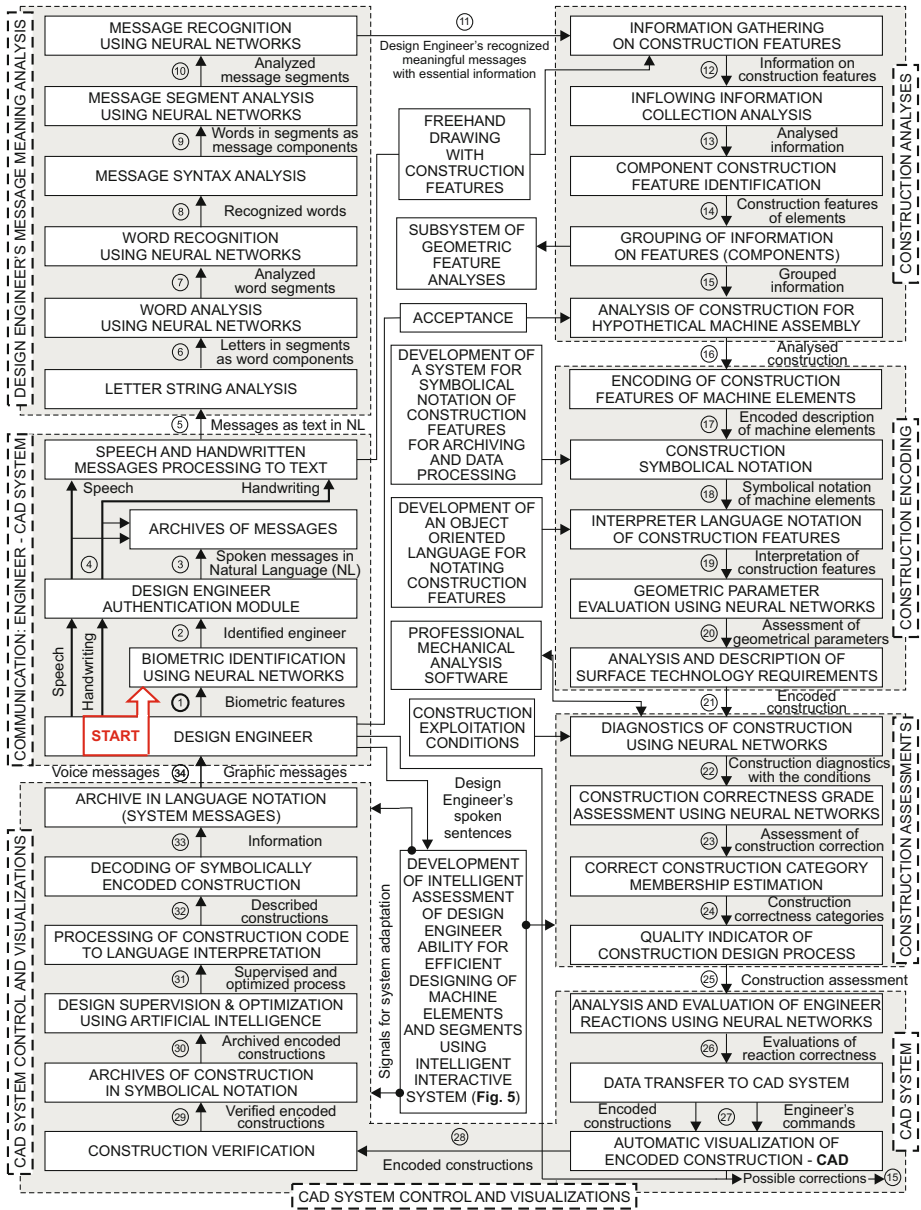
DESIGN ENGINEER'S MESSAGE MEANING ANALYSIS

MESSAGE RECOGNITION USING NEURAL NETWORKS
(10) Analyzed message segments
MESSAGE SEGMENT ANALYSIS USING NEURAL NETWORKS
(9) Words in segments as message components
MESSAGE SYNTAX ANALYSIS
(8) Recognized words
WORD RECOGNITION USING NEURAL NETWORKS
(7) Analyzed word segments
WORD ANALYSIS USING NEURAL NETWORKS
(6) Letters in segments as word components
LETTER STRING ANALYSIS
(5) Messages as text in NL

COMMUNICATION: ENGINEER - CAD SYSTEM

SPEECH AND HANDWRITTEN MESSAGES PROCESSING TO TEXT
Speech | Handwriting
ARCHIVES OF MESSAGES
(4) (3) Spoken messages in Natural Language (NL)
DESIGN ENGINEER AUTHENTICATION MODULE
(2) Identified engineer
BIOMETRIC IDENTIFICATION USING NEURAL NETWORKS
(1) Biometric features
START — DESIGN ENGINEER
Speech | Handwriting
Voice messages (34) Graphic messages

(11) Design Engineer's recognized meaningful messages with essential information

FREEHAND DRAWING WITH CONSTRUCTION FEATURES

SUBSYSTEM OF GEOMETRIC FEATURE ANALYSES

ACCEPTANCE

DEVELOPMENT OF A SYSTEM FOR SYMBOLICAL NOTATION OF CONSTRUCTION FEATURES FOR ARCHIVING AND DATA PROCESSING

DEVELOPMENT OF AN OBJECT ORIENTED LANGUAGE FOR NOTATING CONSTRUCTION FEATURES

PROFESSIONAL MECHANICAL ANALYSIS SOFTWARE

CONSTRUCTION EXPLOITATION CONDITIONS

Design Engineer's spoken sentences

DEVELOPMENT OF INTELLIGENT ASSESSMENT OF DESIGN ENGINEER ABILITY FOR EFFICIENT DESIGNING OF MACHINE ELEMENTS AND SEGMENTS USING INTELLIGENT INTERACTIVE SYSTEM (Fig. 5)

Signals for system adaptation

CONSTRUCTION ANALYSES

INFORMATION GATHERING ON CONSTRUCTION FEATURES
(12) Information on construction features
INFLOWING INFORMATION COLLECTION ANALYSIS
(13) Analysed information
COMPONENT CONSTRUCTION FEATURE IDENTIFICATION
(14) Construction features of elements
GROUPING OF INFORMATION ON FEATURES (COMPONENTS)
(15) Grouped information
ANALYSIS OF CONSTRUCTION FOR HYPOTHETICAL MACHINE ASSEMBLY
(16) Analysed construction

CONSTRUCTION ENCODING

ENCODING OF CONSTRUCTION FEATURES OF MACHINE ELEMENTS
(17) Encoded description of machine elements
CONSTRUCTION SYMBOLICAL NOTATION
(18) Symbolical notation of machine elements
INTERPRETER LANGUAGE NOTATION OF CONSTRUCTION FEATURES
(19) Interpretation of construction features
GEOMETRIC PARAMETER EVALUATION USING NEURAL NETWORKS
(20) Assessment of geometrical parameters
ANALYSIS AND DESCRIPTION OF SURFACE TECHNOLOGY REQUIREMENTS
(21) Encoded construction

CONSTRUCTION ASSESSMENTS

DIAGNOSTICS OF CONSTRUCTION USING NEURAL NETWORKS
(22) Construction diagnostics with the conditions
CONSTRUCTION CORRECTNESS GRADE ASSESSMENT USING NEURAL NETWORKS
(23) Assessment of construction correction
CORRECT CONSTRUCTION CATEGORY MEMBERSHIP ESTIMATION
(24) Construction correctness categories
QUALITY INDICATOR OF CONSTRUCTION DESIGN PROCESS
(25) Construction assessment

CAD SYSTEM

ANALYSIS AND EVALUATION OF ENGINEER REACTIONS USING NEURAL NETWORKS
(26) Evaluations of reaction correctness
DATA TRANSFER TO CAD SYSTEM
(27) Encoded constructions | Engineer's commands
AUTOMATIC VISUALIZATION OF ENCODED CONSTRUCTION - CAD
Possible corrections (15)
(28) Encoded constructions

CAD SYSTEM CONTROL AND VISUALIZATIONS

ARCHIVE IN LANGUAGE NOTATION (SYSTEM MESSAGES)
(33) Information
DECODING OF SYMBOLICALLY ENCODED CONSTRUCTION
(32) Described constructions
PROCESSING OF CONSTRUCTION CODE TO LANGUAGE INTERPRETATION
(31) Supervised and optimized process
DESIGN SUPERVISION & OPTIMIZATION USING ARTIFICIAL INTELLIGENCE
(30) Archived encoded constructions
ARCHIVES OF CONSTRUCTION IN SYMBOLICAL NOTATION
(29) Verified encoded constructions
CONSTRUCTION VERIFICATION

CAD SYSTEM CONTROL AND VISUALIZATIONS

Fig. 2. Block diagram of a new concept of intelligent interactive automated systems for design of machine elements and assemblies on the basis of its features described in a natural language

The proposed intelligent interactive system between CAD systems and design engineers is capable of adaptation to the design engineer through an assessment subsystem that evaluates human ability for efficient designing of machine elements and assemblies using intelligent interactive systems between the assessment subsystem and the design engineer. The assessment subsystem allows for intelligent adaptation by determination of parameters of the natural language interfaces. The system also allows for adjustment of the level of automated supervision of design processes. The intelligent assessment subsystem of design
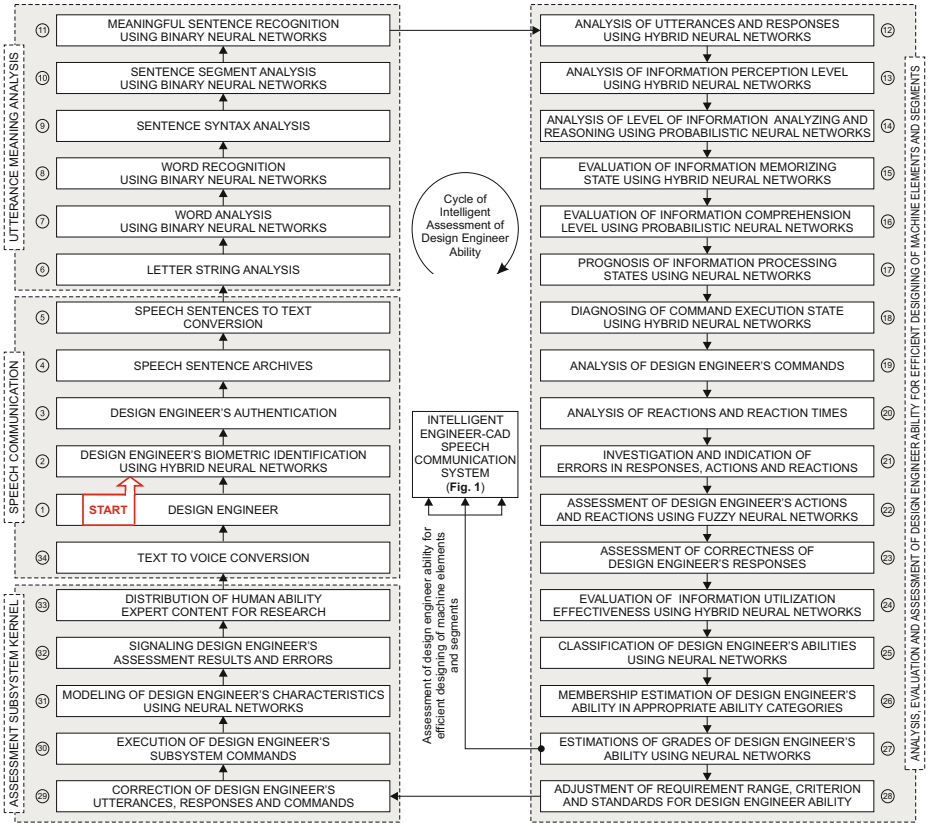
Fig. 3. Block diagram of a new concept of the intelligent assessment subsystem of design engineer's ability for efficient designing

engineer's ability performs adaptation of the designing system in a cycle presented on Fig. 3. After the sentence meaning analysis of the design engineer's utterance, response or message, the recognized meaningful sentences are subject to analysis, evaluation and assessment of the design engineer's ability for efficient designing. The assessment subsystem analyses the user's utterances or responses, and the level of information perception. It also evaluates the level of

analyzing and reasoning of information. Then the constructions after the complex processes of analyzing, encoding and assessments are further processed with the CAD system control and visualizations, which is also composed of several specialized modules.

The intelligent designing system allows for optimal control of CAD systems using natural language communication by speech, handwriting and freehand drawing. The messages are processed by the intelligent interface using artificial intelligence methods. The processing involves meaning analysis of words, messages and sentences in a natural language. Therefore the system is capable of designing correct and optimal constructions of machine elements and assemblies. It is also capable of determination of optimal design process parameters and progress decisions with the aim of supporting the design engineer.

The novelty of the system also consists of inclusion of several layers for symbolic notation of construction features and archiving and processing of construction description data using a new object oriented language for construction.

4   Experimental Results

The experimental research of the developed new intelligent designing system allowed to achieve the following research work:

1. Development of a system of construction symbolic notation of element features.
2. Development of bases of a new language for notation, archiving and processing of data concerning construction description (hypertext object oriented language for construction).
3. Development of a specialized interface of voice communication between design engineers and the system of automatic feature recording and creating drawings of the designed elements.
4. Development of improved methods for recognition and processing of voice messages.
5. Development of new algorithms for recognition of handwriting and freehand drawing.
6. Development of elementary procedures of creating of a symbolic notation of construction basing on its description in a natural language using artificial intelligence.
7. Development of elementary procedures of creating of the notation basing on the symbolic notation.
8. Verification of the developed methods of creating of construction notation basing on its description in a natural language, for the following classes of machine elements: shafts, axles, spindles, gears, discs and others.
9. Assessment of quality of generated projects in the aspects of:
   (a) Conformity with the features of standard constructions,
   (b) Correctness of selection of tolerance, definition of dimensions, and dimension chains,
   (c) Correctness of construction of untypical element features.

10. Development of improvements and modifications of algorithms for design procedures and data processing. Application of constructional probability theory in the creation process of ordered variants of machine element constructions. Aggregation of construction standards for verification and evaluation of the system.
11. Development of modifications concerning the new language for construction notation and object language of construction description (with working name KM-XML, and KM-HTML).
12. Development of new directions for further research. Elaboration of foundations for realization of a development project and implementation of the work results.

5   Conclusions and Perspectives

The main effect of the realization of the research was the following:

1. Higher level of designing through complete advantage of designers' creativity, relieving designers from doing tasks involving creation of graphical image of elements.
2. Increase of rapidity of design process, particularly of complex elements.
3. Convenience of modifications and evaluation of many solution variants.
4. Automation of the most laborious tasks in the design of machine elements.
5. Development of an object oriented language for construction notation and methods for symbolic notation.
6. Improvement of operations of data processing and archiving.
7. Development of an artificial intelligence system aiding design processes.

The main results of the research are brand new effective systems for designing machine elements without the use of standard interfaces for inputting data. Directing of designer's creative potential to the conceptual tasks with relieve from performing graphical tasks with use of simple systems for communication with computer applications. The technological effect of the research is appreciable reduction of time for implementation of new and modern products.

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