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M. Litvinenko[1], S. Shylo[1], I. Borozenets[1], V. Mazharov[2]

[1] *Ivan Kozhedub Kharkiv National Air Force University, Kharkiv*
[2] *Kirovohrad Flight Academy of National Aviation University, Kropivnytskyi*

METHOD OF REPRESENTATION OF THE SURFACE STRUCTURE OF MESSAGES ON THE RESTRICTED NATURAL LANGUAGE OF THE OPERATORS OF AUTOMATED AIR TRAFFIC CONTROL SYSTEM

The paper proposes a method for processing and formalizing the messages of operators in automated air traffic control system on limited interaction language. The model of the limited natural interaction language is obtained, that takes into account peculiarities of the professional language of users and the internal language of the intellectual system. Texts of a limited natural language represent a surface structure of the language of interaction, expression of the internal language of interaction of the intellectual system represent a level of meaning. The surface - syntactic level of the language is specified by the structure of the noun phrases, the deep level by the trees of the syntactic subordination, in which semantic relations are established. At the same time, the links between the word forms are established not only with the knowledge of the syntax of the language, but also with the knowledge of the subject area and the semantics of the internal language intellectual system. To transfer from one level to another, it is suggested to use a multi-level description of the interaction language. Intermediate levels at transition from the surface structure of the messages to the level of meaning are noun phrases and the trees of the syntactic subordination.

Keywords: *informational model, interaction language, noun phrase, trees of syntactic subordination.*

Introduction

Task assignment. Tasks of air traffic control (ATC) are characterized by complexity and high dynamics of changing conditions of situation. Data for taking the decision by operators in the automatic air traffic controlled systems (AATCS) don't often have concrete space-time characteristics. Meanwhile, the informational support of decision making processes by operators in AATCS must provide the effective solving of functional tasks in the conditions of non-complete information and in time limits [1–2; 14].

Analysis of modern state of information support system AATCS operators testifies about insufficient processing of questions about removal of contradictions for completeness of the informational models (IM) and efficiency of administrative decision- making process and opportunities of present methods and facilities on their achievement [1; 5; 14].

First of all, questions about the development and improvement of linguistic means of interaction of ATCS operators with the use of the decision-making support system (DMSS) are needed to be working out. This aspect is directed for the optimization of dialog organization process in the link a man-ATCS operator, and allows to increase the completeness of IM and efficiency of administrative decision- making process as a result [3–14].

The development of linguistic methods with the construction of limited natural interaction language of users, including specific features of subject area, grammatical, syntactic and semantic features of language constructions patterns are actual in practical aspect .With the realization of further opportunity of moving to the level of internal language of communication of intellectual system, and to formalize the process of transferring from surface level of subject area features to the level of meaning.

Analysis of last researches and publications. The analysis of existent interaction language models testifies that the offered language models are based on multilevel description as morphological, syntactic, semantic and pragmatic descriptions. In order to get the corresponded structure of interaction language in different language models various linguistic and extra linguistic methods are used. The choice of them depends on the specific of subject area where it is necessary to provide the required quality of functional tusks solving [3–14].

Taking into account the specifics of tasks that are settled by ATCS operators, method and models of communication on the limited natural interaction language of operators with possibility of transferring to the level of internal interaction language of intellectual system for making the model of dialogue in a link a man-operator – intellectual system require the development. That will take into account the subject area specific, grammatical, syntactical and semantic features of language constructions.

Purpose and tasks of the research.Known methods and forming methodologies of IM control that exist in airspace don't take into consideration difficulties of message creations in AATCS on the limited interaction

language, does not provide the formalization of this process taking into account the specialties of subject area, and they do not take into account the grammatical, syntactical and semantic features of the limited language models of users. It is necessary to work out the method of giving the messages in AATCS on the limited natural interaction language of users that will take into account the specialties of subject area, grammatical, syntactical and semantic features of language constructions. As a result, the received system of formalization of communication a man – AATCS operator – must allow to realize the co-operation of internal language system with a limited natural interaction language of users.

Main part

Problem definition of the limited natural interaction language model development. Two levels of interaction language (IL) should be distinguished at the development of IL in the interests of ATC tasks solving.

The first level is given by expressions on the limited natural language (LNL), in other words – L-language, that is examined as a surface structure of IL. It represents the internal ideas of subject field users to solve the tasks, aims that are achieved at in the process of performing ATC functional tasks. On the basis, that users communicate each other in professional language, well understand the simulated processes of subject field, it is quite natural that they quite understand the surface level of IL. On the other hand, the L-language level is not clear for DMSS AATCS, because DMSS as an intellectual system can "understand" only S – language (internal system language) [6].

In fact, S-language is the level of L-language content for DMSS. That`s why in the process of communications of users on surface international language (SIL) it is necessary transform L-language texts – in expressions of S-language. Formally, the process of transformation in general can be given in the next way.

Let some set of L-language fragments are given and the intellectual system internal language (S-language) is detected. The task of translation consists in transformation of the expressions 1-L, where 1 – set of all L-language expressions, in some text c-C, where c – set of all defined on the set L, it allows to make the adequate text on the message 1.

Basic assumptions and limitations. Taking into account peculiarities of language material that are used for solving of functional tasks by AATCS operators, the main focus of IL model development should be concentrated on the following thing – at a minimum presumable loss of the language maximally satisfy the requirements of information completeness and efficiency of decision-making process. It depends on the fact that at insignificant increase of expressive means of language, degree of complexity of word processing algorithm increases incomparably more [6–7; 13].

To solve this problem, the following system of limitations and allowances is suggested to be accept.

1. The forms of sentences that are used by users comes down to the following:

– interrogative – to search out some facts, necessary information clarification;

– narrative – to change and supplement of necessary information in the base of the intellectual system knowledge;

– directive – to follow instructions on the task, and to follow some actions.

2. The limits of the language structure

– simple sentence can include not more than one verb;

– ellipses (omitted constructions) and anaphoric references cannot be used.

3. Lexical structure of the sentences does not assume meaningful limitations, except prohibition of parenthetical words, infrequent and insignificant constructions.

The dictionary that is used includes within 2500 words, 2300 of them are the technical terms (A-320, B-747, flight number, name of airports and places of their location etc.), the rest words are generic terms of language of system users.

Limits on L-language also lead to narrowing of use of S-language. The results of analysis of possibilities of natural language formalization testify than on the level of separate sentence can be given the description of simplified structure of S-language with the use of pragmatic functions (PF) which let next kind of knowledge manipulation [7]:

PF_i<role of object: name of object, S_I;
(role of subobject : the name of subobject, S_I;
..... (1)
role of subobject : the name of subobject, S_I)>,

where S_I service information about the theory of object, to which procedures, quantifiers, modalities, operators, comments, presence evaluation belong.

For realization of transition possibility from the limited natural interaction language to internal intellectual system interaction language it is necessary to define the number of interaction levels and develop the procedure that allows to transfer from one level to another.

Model of limited natural interaction language. For transition from the text given on natural language to its meaning , that is given in the form of the expressions on S-language, we will examine the

<Vectoring, object – process,
(PAIPAS: ATM- 17;
PIDP: take the flight level 4;
BPOS: to point R1)>,

where PAIPAS, PIDP, BPOS – roles, that next subobjects perform: "passenger aircraft that carries out international

passenger air service", "point in determined position", "boundary parameters of the space". Comparing surface and deep levels of text presentations, we should determine that the transformation process TEXT SENSE must consist in the search of morphisms (roles), that enter into the object, names of subobjects(features), through which description of this object execute. Provided that the names of the objects and also morphisms (roles) that enter into the object and coming out of it are described by the whole groups of words (word-combinations), it is necessary to take into account the connections between words and word combinations on different levels. As a result, it allows to make the synthesis of trees of syntactic submission (TSS). Exactly the TSS instrument most advisable to use as a means of forming the depth structure – expressions of S-language [3; 10].

Essence of method of text presentation with the use of TSS vehicle is in the following.

Let x is an arbitrary unobstructed not empty chain of dictionary, and X is some set of not empty subsets x. Elements x are called informational groups (IG). Graph $\{X \rightarrow\}$ is called TSS on X, when it satisfies to the next axioms [11]:

A1. X contains x and all single-element subsets x;
A2. If E1, E2 $\in$ X, then or E1$\cap$E2 = 0, or E1$\subseteq$E2, or E2$\subseteq$EI;
A3. If E1, E2 $\in$ X and E1 $\rightarrow$ E2, then E1 and E2 is included in the same IG;
A4. If E1 $\rightarrow$ E2 and E is optional to IG, then E and E1 $\cup$ doesn't mesh
A5. If E1 $\rightarrow$ E2, E3 $\rightarrow$ E4, then sets of E1 $\cup$ E2 and E3$\cup$ E4 doesn't mesh.

Axioms A1, A2 describe set x, A3 - A5 is a ratio "$\rightarrow$". The tree of syntactic submission is surface-syntactic level of interaction language. In this case, marks should attribute to both nodes and arcs of the graph.

According to the analogy with marked component systems it is advisable to include marked TSS (MTSS).

The next tuple can determine the formal presentation of marked:

$$< X, \rightarrow, Z\ \phi>, \qquad (2)$$

where $\{X \rightarrow\}$ - the system of nominal groups, Z – final sets, ϕ – reflection of ark graph sets $\{X \rightarrow\}$ to Z. Graphical expression TSS for the example we examine is in the fig. 1.

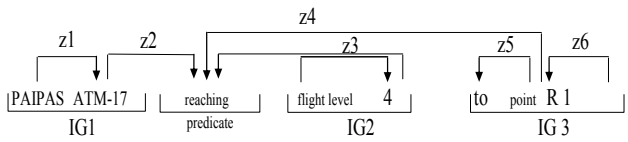


Fig. 1. Structure of TSS

Elements of z are syntactic submission ratio, determined by the parts of speech function in a sentence. In an order to realize the possibility to get a structure that is isomorphic to the directed network for the category model of knowledge, it is offered, by contrast to conventional arrow direction from "owner" to "servant" to change on the reverse image - from "servant" to "owner". At research of IG and relations within IG, we should determine that the most complete IG it can be set by a next chain:

$$CC, Ob, Pr, Qu, CN, ON, Ad, N, I \qquad (3)$$

where Cc is coordinating conjunction, Ob – objection, Pr – preposition, Qu – quantified word, CN – cardinal numeral, ON – ordinal numeral, Ad – adjective, N – noun, I – name.

In practice, next features should be taken into account: during realization of IL to IG, as a rule, not all elements of the chain include (16). Relations between members in IG at synthesis and analysis of IN provoke the biggest interest. Basing on the results of modern linguistic researches and taking into account semantic links between word forms, and also basing on special features of subject area and worked internal language intellectual system, we can determine next kinds of relations for examined problem.

The name (N). In the form of the name can be ordinal numerals, lines in inverted commas. For example,

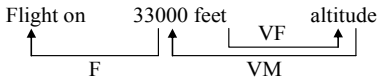
Airbus A-319 Tunisair $\xleftarrow{\text{Im}}$ "HANNIBAL",

flight PS 713 $\xrightarrow{\text{Im}}$ Boeing 737 .

The feature (F). This relation, as a rule, expounds connection between noun and adjective in IG. For example,

sport $\xrightarrow{F}$ aircraft , free $\xleftarrow{F}$ flight level .

The feature (F). The measure value feature (VM). The value feature (FV). These relations appear in the group of words that characterize a certain object. For example, for the group of words "flight on height of 33000 feet" are set next links:



If the value feature is given qualitatively, for example, small height, then the relations qualitative value (Qu) feature is set:

According to syntax, cardinal numerals and quantified words can stay with nouns. In such case the next relation can be established "cardinal value" (Ca) and "quantifier" (Qa). Also many nouns can stay definitions to the nouns of other groups. Such relations are "Attributive" (Atr). In some IG, like "landing area", "turbulence area", nouns are making dependent combinations that have independent interpretation. This structures must be examined as separate concepts.

Some elements of language constructions, for example predicate and circumstances can be different parts of speech. Circumstances, as a rule, are nouns in indirect cases, adverbs and verbs or word combinations with these parts of speech. The role of circumstances consists in definition of situation (Def) that is described by main word, for example, vectoring $\xleftarrow{\text{Def}}$ simultaneously resulting in the new role specifying the situation. This type of relation is used for determination of connection between the IG nouns and interrogative words "What", "How many".

If the main word is expressed by combination of verb and nominal group where the main word is a verbal noun, then the last carries the basic semantic loading, the verb has an axillary role. Between them the relation "axillary" (Ax) become. For example, provide $\xleftarrow{\text{Supp.}}$ escort .

Comparison of expression with some moment of time can be achieved by the use of verb in corresponding time, and modality is got due to the use of words that express alethic, deontic, and epistemic modality. For such cases the relations of modality (Mod) should be used.

For example, necessary $\xrightarrow{\text{Mod}}$ separate , clear $\xrightarrow{\text{Mod}}$ landing .

Semantics of relation is determined, as a rule by semantics of "servant".

The operator relations (Op) is used with main word with negative parts and with such words as: somebody, anybody with IG noun. To distinguish IG it is necessary to consider the following knowledge about the interaction language: gr – grammatical information about the word forms (part of speech, gender, number, case etc.); sint – syntactic information about word forms (with what parts of speech and how they combine); sem – semantic information about the word forms (denoting notion, semantic combination with other word forms etc.).

To distinguish IG in IL and to make links between words in IG structure, the next rule should be used:

$$H: S_i(gr_i, sint_i, Sem_i); S_j(gr_j, sint_j, sem_j):D \rightarrow R_{ij} \quad (4)$$

where H – possible conditions to apply the rule (for example, consistency of gr, sint and to sem information); D – information about the place of word forms in phrase; Rij set connections between the word forms and j.

In practical applications, at making links between IG and other parts of speech, the role of some word forms are determinative. First of all, it is verbs and verb form (verbal nouns, adjectives, etc).

For the groups of words that have the main semantic meaning it is suggested to enter a term - main word group (MWG).

Complex of MWG semantic and syntactic information is the model of control (MC). In general MC can be given in the next way:

$$r_{k1}:S\ (gr_{k1}, sem_{k1}), \ldots, r_{kn}:S(gr_{kn},sem_{kn}), \quad (5)$$

where r_{ki} (i=1., n) – i-a role, that the role that word forms execute in k-model of control, grk_{ki} sem_{ki} – complex of grammatical and semantic information about the nominal group.

For example, for the concept of "vectoring" the description with the help of the next semantic features (included roles or morphisms) can be given: to be devise of vectoring (DV), to be object of vectoring (OV), to be place in the air (PIA), to be boundary parameter (BP), to be moment of time (MOT). For the example that is examined, the partial constituent of concept of "vectoring" are IG – ATM-17, flight level – 4, to point R1. For the case, if grammatical and semantic information are identical with corresponding data of control system, the structure of sentence, shown on the fig. 1, will be the next (fig. 2):

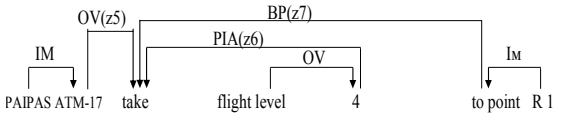


Fig. 2. Semantic analysis

It is worthy of note that z5, z6 and z7 (fig. 2) present the role names, which subobjects make in the object of "vectoring".

Fig. 2 demonstrates that the following structure describes syntactic and semantic structure of the example phrase (deep level of IL) and it is the intermediate chain between TSS and level of meaning.

Meanwhile, the process of transition from the superficial level of IL to the level of meaning can be described in the form of consistent transformation:

$$l \xrightarrow{\mu_1} TSS \xrightarrow{\mu_2} \text{deep level} \xrightarrow{\mu_3} l, \quad (5)$$

where l, s – expressions of limited natural interaction language and internal system language, μ1, μ2, μ3 – procedures, that allow to change from expressions of limited interaction language to the building of TSS, semantic analysis and internal system supply.

After realization of the indicated operations the sentence will take the next form:

< object-process, vectoring,
(OV: PAIPAS ATM- 17;
BP: to the point R1;
PIA: flight level 4) >.

As is seen from the expression structure, the place of subobjects in S-language expressions can be selected randomly, and concrete information is defined according to the role which corresponding subobject execute.

Hereby, we receive the model of a limited natural interaction language that takes into account grammatical, syntactic and semantic features of language construction of subject area that allows to state about achieving the goal of the research.

Conclusions

The model of the limited natural interaction language for AATCS operators is worked out, it takes into account the specific of ATC functional tasks considering grammatical, syntactic and semantic features of language construction.

Features professional language of users and DMSS AATCS internal language allow, in a result, to get the model of the limited natural interaction language that has the next features: texts of the limited natural language is the surface structure of interaction language, expressions of S- language is the level of meaning; to transfer from one level to another multilevel description of interaction language should be used; intermediate levels at transition from the superficial structure of the messages to the level of meaning are noun phrases and the trees of the syntactic submission

The received model allows to realize the interlevel process of interaction between the S-system internal language with the limited natural interaction language of users.

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Відомості про авторів:

Литвиненко Михайло Іванович
кандидат технічних наук доцент
заступник начальника Харківського національного університету Повітряних Сил ім. І. Кожедуба з навчальної роботи,
Харків, Україна
https://orcid.org/0000-0002-1088-5717

Information about the authors:

Mikhail Litvinenko
Candidate of Technical Sciences Associate Professor
Deputy Head of Ivan Kozhedub Kharkiv National Air Force University for Educational Work,
Kharkiv, Ukraine
https://orcid.org/0000-0002-1088-5717

Шило Сергій Георгійович
кандидат технічних наук доцент
викладач кафедри Харківського національного
університету Повітряних Сил ім. І.Кожедуба,
Харків, Україна
https://orcid.org/0000-0001-5782-552X

Serhiy Shylo
Candidate of Technical Sciences Associate Professor
Lecturer of the Department of Ivan Kozhedub Kharkiv
National Air Force University,
Kharkiv, Ukraine
https://orcid.org/0000-0001-5782-552X

Борозенець Ігор Олексійович
кандидат технічних наук
старший викладач кафедри Харківського національного
університету Повітряних Сил ім. І. Кожедуба,
Харків, Україна
https://orcid.org/0000-0003-1162-9966

Igor Borozenets
Candidate of Technical Sciences
Senior Instructor of the Department Ivan Kozhedub Kharkiv
National Air Force University,
Kharkiv, Ukraine
https://orcid.org/0000-0003-1162-9966

Мажаров Володимир Сергійович
викладач кафедри Кіровоградської льотної академії
національного авіаційного університету,
Кропивницький, Україна
https://orcid.org/0000-0002-9535-0841
e-mail:mazharovpp@gmail.com

Volodymyr Mazharov
Lecturer of the Department of the Kirovohrad Flight Academy
of National Aviation University,
Kropivnitskyi, Ukraine
https://orcid.org/0000-0002-9535-0841
e-mail:mazharovpp@gmail.com

МЕТОД ПОДАННЯ ПОВЕРХНЕВОЇ СТРУКТУРИ ПОВІДОМЛЕНЬ НА ОБМЕЖЕНІЙ ПРИРОДНІЙ МОВІ ВЗАЄМОДІЇ ОПЕРАТОРІВ З АВТОМАТИЗОВАНОЮ СИСТЕМОЮ УПРАВЛІННЯ ПОВІТРЯНИМ РУХОМ

М.І. Литвиненко, С.Г. Шило, І.О. Борозенець, В.С. Мажаров

В роботі запропоновано метод обробки та формалізації повідомлень операторів автоматизованої системи управління повітряним рухом на обмеженій мові взаємодії. Отримано модель обмеженої природньої мови взаємодії, що враховує особливості професійної мови користувачів та внутрішньої мови інтелектуальної системи. Тексти обмеженої природньої мови являють собою поверхневу структуру мови взаємодії, вирази внутрішньої мови інтелектуальної системи являють собою рівень сенсу. Поверхнево-синтаксичний рівень мови задається структурою іменних груп, глибинний рівень – деревами синтаксичного підпорядкування, в яких встановлено семантичні відношення. При цьому зв'язки між словоформами встановлюються не тільки з використанням знань про синтаксис мови, але і знань з проблематики предметної області, та семантики внутрішньої мови інтелектуальної системи. Проміжними рівнями при переході від поверхневою структури повідомлень до рівня сенсу є іменні групи та дерева синтаксичного підпорядкування.

Ключові слова: *інформаційна модель, мова взаємодії, іменні групи, дерева синтаксичного підпорядкування.*

МЕТОД ПРЕДСТАВЛЕНИЯ ПОВЕРХНОСТНОЙ СТРУКТУРЫ СООБЩЕНИЙ НА ОГРАНИЧЕННОМ ЕСТЕСТВЕННОМ ЯЗЫКЕ ВЗАИМОДЕЙСТВИЯ ОПЕРАТОРОВ С АВТОМАТИЗИРОВАННОЙ СИСТЕМОЙ УПРАВЛЕНИЯ ВОЗДУШНЫМ ДВИЖЕНИЕМ

М.И. Литвиненко, С.Г. Шило, И.А. Борозенец, В.С. Мажаров

В работе предложен метод обработки и формализации сообщений операторов автоматизированной системы управления воздушным движением на ограниченном языке взаимодействия. Получена модель ограниченного естественного языка взаимодействия, учитывающая особенности профессионального языка пользователей и внутреннего языка интеллектуальной системы. Тексты ограниченного естественного языка представляют собой поверхностную структуру языка взаимодействия, выражения внутреннего языка взаимодействия интеллектуальной системы представляют собой уровень смысла. Поверхностно-синтаксический уровень языка задается структурой именных групп, глубинный уровень – деревьями синтаксического подчинения, в которых установлены семантические отношения. При этом связи между словоформами устанавливаются не только с использованием знаний о синтаксисе языка, но и знаний по проблематике предметной области, и семантики внутреннего языка взаимодействия интеллектуальной системы. Промежуточными уровнями при переходе от поверхностной структуры сообщений к уровню смысла являются именные группы и деревья синтаксического подчинения.

Ключевые слова: *информационная модель, язык взаимодействия, именные группы, деревья синтаксического подчинения.*