Modeling of Dialogue Reasoning and Its Applications

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Abstract

The paper investigates phenomena of human-computer interaction, dialogue reasoning as question answering process, its modeling and effective application in network and collaborative environments.

This paper briefly introduces a concept of "dialogue reasoning" as a practical reasoning used in problem solving and decision-making. A scientific work group "Question Answering Technologies, Systems and Means" [1] developed the methodology base of applied question answering and currently uses the dialogue reasoning models in a number of practical applications, e.g. in computer-aided design. Modeling of dialogue reasoning is the basis of our approach to human-computer interface construction.

1. Introduction

A phenomenon of human-computer interaction as one type of our reality is determined by the specific *question answering* activity of a man [2]. The last years it has got the steady interest of many researchers in different fields (Computer Science, Psychology, Natural Language Processing, Logics, Philosophy and etc.) [3, 4]. The members of the scientific work group "Question Answering Technologies, Systems and Means" consider that they have found productive understanding of the nature of human-computer interaction. We consider that human reasoning in problem solving or decision-making (single or collaborative) and an access to experience are realized through special kind of reasoning - *Dialogue Reasoning*, or Question Answer process (Q&A), so it is open for registering, storing, transforming, analysis and rational use. Methodology of our work group includes a system of basic concepts and research statements for modeling of dialogue reasoning in computer environment and takes into account experience of interaction of a person with this environment [4, 5, 6, 7].

Dialogue reasoning is a practical reasoning, which can be represented by a guided event network with Q&A nodes connected by question-answer relations. In this domain the basic concepts of dialogue reasoning, i.e. "Question" and "Answer" and the certain types of Q&A relations, are principal. "Question" is considered a mismatch between the potential experience necessary to implement a decision and the real experience of a person. The mismatch (question) specifies the necessity of its improvement through construction of the suitable answer. To model the process of reasoning and we need to determine the types of questions and answers and the set of Q&A relations. This paper mentions only the types of models of dialogue reasoning and its applications.

2. Modeling of dialogue reasoning

This section briefly introduces the basic points of the research in dialogue reasoning presentations. It begins with the idea of structuring the reasoning in special Q&A protocols, and proceeds by the development of the adequate Q&A models.

It is suggested using the special Q&A style and form of reasoning in problem solving in order to open the possibilities for its question-answer analysis. These means are based on step-by-step registering of dialogue reasoning as the special protocol (Q&A protocol) of intellectual work. The basic tasks of its processing are:

1) controlling of the decision-making process;

2) reduction of informational ambiguity;

3) accumulation and systematization of experience in intellectual reasoning and decision-making.

Each of the mentioned tasks is based on the model of the Q&A protocol in its current state and the system of corresponding operations. Such models of dialogue reasoning as event Q&A networks, PETRI-nets and PERT-nets are developed, tested and applied in a number of systems [1], and are to be mentioned below.

2.1 Q&A protocoling

The structure of Question Answering should include mechanisms allowing to register and record questions as the data base of templates for their storing and repeated Q-action, e.g. for simulating of decision-making. The means are based on step-by-step recording of questions and answers in the special protocol (Q&A-protocol), i.e. we suggest using the special Q&A style and form of reasoning in problem solving. Interactive recording of reasoning is submitted in Q&A intellectual artificial interface of the decision support systems developed by the work group.

Q&A-protocol registers decision making as a research experiment, thus representing «primary measuring information» of its process. As the contents of the protocol represents a reasoning, which supports and managers the decision making, this information is also about control facilities used. Besides, the protocol reflects a process of mental activity, so its analysis and processing helps to understand both results and a

cognitive process of the decision-maker who has made the protocol or its part.

Each of the registered Q&A units admits its interpretation as an event essential for decision making that allows considering the protocol as «network of events» ordered in time. The pragmatic version of data abstraction in Q&A-protocols is realized through the adequate mathematical models.

Processing of the registered information is aimed at useful effects, e.g. management, summarizing and ordering of information and experience as "cases" or "scenarios" of activity. Each of the named tasks is based on the model of the Q&A-protocol in its current state (as a Q&A structure) and the system of corresponding operations.

2.2. Basic models of dialogue reasoning

We begin with the pragmatic version of data abstraction in its application to Q&A-protocols, and it supposes to find and chose some mathematical model adequate to Q&A-protocol. It is easy to agree that graph representation is appropriate for modeling of dialogue reasoning, and here it will be presented 2 types of graph models (G1-model and G2-model).

G1-Model

Q&A-protocol is presented as a graph G1(Q, A, W), where W is a system of connections of nodes reflecting question-answer relations of all types. The basic types of Q&A relations are determined and classified [8].

We consider that each node bj (from the set $B = \{b_j\} = Q \cup A = \{Q_i\} \cup \{A_i\}$) codes a question or answer as "event" (in a database structure) of a current reasoning as:

$b_j : N_j, T_j, t(b_j), p(b_j),$

where:

- N_j - unique name of event (identifier of a particular question or answer);
- T_j - description of event in natural - professional language L;
- $\{ t(b_j)\}$ - set of the temporal characteristics coordinated with causal and the dynamic relations;
- $\{ p(b_j)\}$ - determines a person or the executive team in collaborative work, so as a user of their results

Graph G1 is dynamic formation developing as a result of connection of the next node. The model makes possible examination of Q&A-protocol as a network of events that provides various functions, e.g. «scrolling» or «supervision» of the whole network or its fragments.

G2-Model

G2-Model is also a network class and is more informative than G1-model. The purpose of the model is to distinguish the types of the nodes and relations in Q&A-graph:

$$G2 = G^{Z}(Z,W1) \cup G^{ZA}(Z, A1, W2) \cup G^{Q}(Q,W3) \cup G^{QA}(Q,A2,W4)$$

where:

$G^{Z}(Z,W1)$ - guided graph determined on the set of nodes $Z = \{Zi\}$, each of which specifies a task or subtask, and the set of arches $W1 = \{(Zi, Zj)\}$, where nodes are connected by the relation of submission of a subtask Zj to a task Zi;

G^{ZA} (Z, A1, W2) - guided bipartate graph connecting (through pairs from W2) elements of the set Z to elements of the set A1, $A1 = S \cup H$, in which $S = \{Sj\}$ - nodes indicating «decision» of tasks from the set {Zi}, $H = \{Hi\}$ - «ideas - hypotheses» the decisions of tasks – problems;

$G^{Q}(Q,W3)$ - guided graph which nodes $Q = \{Qj\}$ represent questions of all types, including sets Q1и Z, and are connected by arches from set $W3 = \{(Qi, Qj\}$ modeling relations of submission a subquestion to a question and a question to a task;

G^{QA}(Q, A2, W4) - bipartate graph connecting by arches from W4 the nodes from the set Q to nodes of the set $A2 = T \cup P$, where $T = \{Te\}$ - answers (text) on the appropriate questions, and $P = \{Pm\}$ - answers to questions by action (appropriate procedures of these actions).

2.3. Extended models and the means of systematization

Each particular Q&A network represents a certain dialogue reasoning and the system of Q&A relations open for application in various purposes. Thus, the necessary means of systematization and structuring of experience have been included into this process.

Systematization means are corresponded with the detailization of Q&A network nodes, e.g. the basic role in systematization of texts ({Ti}-node attribute) is done by interrogative Q&A logic, and the temporal set {t(bi)} is structured according to rules of temporal logic.

The class of logic systematizations is expanded with the help of causal logic that provides the application of "scenario" and "cases" in terms of Case-Base-Reasoning approach [7].

The set {p(bi)} determines structure of the executor and/or the user of work and that is useful in collaborative networking environments.

The model of dialogue reasoning (Q&A-process) and its components should be selected proceeding from their practically useful applications.

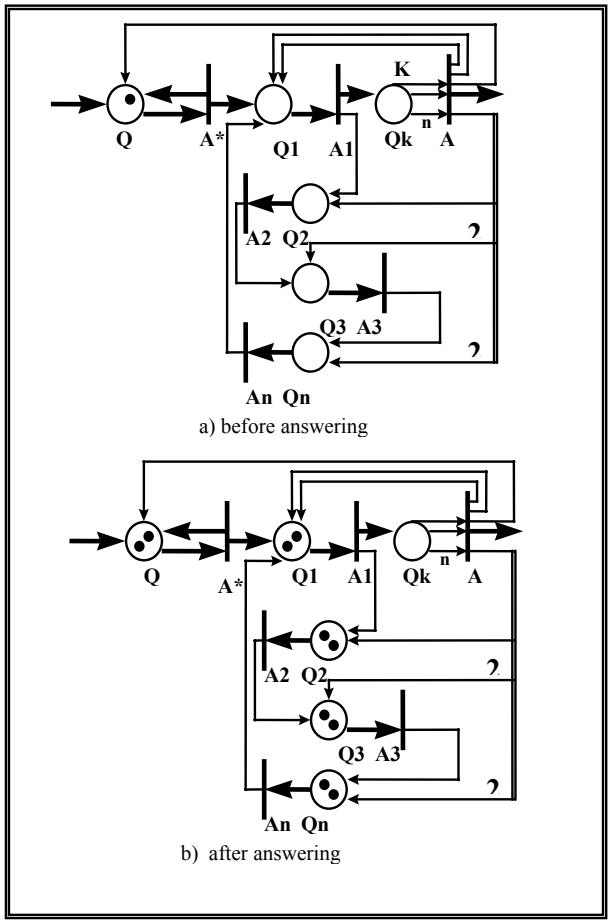
If the model is chosen, the number of its applications and their contribution to the control of an activity depends on an opportunity of transformation of this model into the other forms.

Systematization means also provide transformation of Q&A networks to other useful models well known in Computer Science, i.e. PETRI-nets and temporal management PERT-diagrams with the correspondent functionality and benefits.

PETRI-net model

PETRI-nets got the wide application in the theory and practice of network representation of events. PETRI-nets are used for indication and connection of events with the conditions of their realization [9, 10]. Definition of a particular PETRI-net uses two types of nodes:

- for modeling events (A-transitions),
- for modeling conditions (Q-positions).



"Figure 1. An example of one of Q&A-relations (coordinated progress of answers) in PETRI-net model"

Preconditions (the certain set of positions) are potentially connected with the certain event. Activization of preconditions results in realization of the appropriate events that change a set of conditions and provide the development of the process.

The similar "behaviour" takes place in Q&A-processes when we consider: the set of questions as the real conditions (existing and requiring an adequate reaction) for an answer work; the set of answers as events connected with questions-preconditions.

Hence, for the modeling of dialogue reasoning we can use an apparatus of PETRI-nets. The nature of Q&A-processes results in the certain class of PETRI-nets with the corresponding set of Q&A-relations.

The graphical versions of Q&A-relations are sufficient for transition from real Q&A-structure to its representation as PETRI-net.

These reasoning about an opportunity of representation of Q&A-processes by PETRI-apparatus, and the offered technique of transformation of the initial Q&A-graph into equivalent Petri-models provides an opportunity for "step-by-step" modeling of work dynamics. So, we can use the knowledge of PETRI-theory to support our reasoning to increase the efficiency of control.

The number of the important applications of this model e.g. includes the operative indication of conditions (by markers). This indication effectively reflects the so-called «front of work» (which determines the open nodes or the points for continuation of the interrupted work).

PERT-model of reasoning

A net graph (PERT-diagram, PERT chart) represents informational-dynamic model of a process (complex of works) and is an instrument for rational management of processes (tasks) in activity [11].

The basic features of work complex for modeling with the means of net graphs are:

- an opportunity of its representation as a set of separate interconnected events (works);
- a presence of the certain relations of the order (a sequence of execution of tasks) between events (works);
- a presence of one or many purposes of work.

The network model can be presented as the guided graph with weights (the basic type: events - nodes, work - arch). It allows displaying (with any degree of detailization) the structure and interrelation of a complex of tasks in time.

PERT-diagram of dialogue reasoning considers Q&A structures as a network of tasks each of which has its certain order and temporal characteristics.

Such network can be effectively submitted with the help of PC in tabular or other compact form (e.g. as the temporal diagram).

The application of algorithms of the graph theory allows to calculate the critical paths and gives the bases for the effective analysis, optimization and scheduling our work.

Interpretation of Q&A-protocol as PERT-diagram is adequate to its use as a sample for the repeated (sample) actions.

Besides, the methods of association («sewing») of net graphs (construction «from bottom to top»), and an opportunity of their «integration» (construction «from top to bottom») are used for more convenient representation to the users, that corresponds to principles of descending and ascending design.

3. Applications and Benefits

The mentioned models and means are realized in NetWIQA Decision Support System and chosen in different work modes during problem solving.

The research methodology and specialized systems supporting dialogue reasoning in problem solving open some new applications in its control and management. Let us name a number of them, i.e. the effective monitoring of the design, parallel coordination of the collaborative work and its effective distribution, interactive demonstration of the current state of the design and its potentials, access or training according to the data base of typical decisions (design templates, cases, scenarios and designers' profiles), personification of the designer contribution to the project.

The certain dialogue reasoning of a person, which is registered as the Q&A process, is the model of the individual thinking, and can be used for different research and practical purposes.

We also see some real collaborative solutions benefits at the application of the developed models and technological issues, e.g. our system provides:

- support of human interactions and integration of design processes in the uniform systematization Q&A structure through the clear and powerful intellectual interface;
- function of team members shared activities and actions, and supervising and track the progress of the joint collaborative project and its parts;
- joint problem-solving and decision-making;
- effective learning and inclusion to joint work;
- faster access to information and communication;
- WORM ("write once- read many") concept for design experience storage and usage;
- consideration of human factors and the involvement of workers directly into the development process, which has been noted the important challenge in collaborative work [12].

Commercial approach of the system also helps in addressing industry concerns surrounding the concept of Intellectual Property and personal contribution to the work done.

4. Conclusions

The work group has developed the research methodology and basis of the applied theory revealing the mechanisms of dialogue reasoning and its utility. The bases of the theory are stated in the book "Logics of Human-computer dialogue" [8]. The submitted methodological base of our group has been developed for two decades of research in the field of HCI and Question Answering R&D domain and was checked on practice and use in a number of systems.

The ideas of the authors have been realized in the structure and functionality of Q&A processor (WIQA - Working In Question Answering) constructed to solve the problems of detection, identification, encoding and processing of questions and answers, and their modelling. The network release of Q&A processor (NetWIQA) has been developed and tested to be applied in collaborative decision-making. The basic peculiarity of the NetWIQA processor is human-computer interaction.

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