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Machine Consciousness and Question Answering

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ABSTRACT

In the present paper it is proposed that Machine Consciousness can be implemented by using either Finite State Automata or Production Systems. In both cases a possible behavior that may be characterized as exhibiting consciousness is the generation of an explanation of how it generates its final output. The implementation of Machine Consciousness techniques as applied to the technology of Question Answering is illustrated with our AMYNTAS Deductive Question Answering system. This system is described and it is shown how it generates in addition to an answer to the input question an explanatory report in natural language of the steps followed by the computation for the generation of an answer. Our implemented system is based both on finite state automata and on production systems and generates explanations in two ways while Question Answering from texts. One way is based on the state change path followed by an automaton and the other is based on the chain of productions activated during generating an answer. Our system was evaluated for precision and recall with a biologist as judge for information extraction from biological texts as well as for flexibility by showing that it can easily be adapted to three new domains. In contrast to our AMYNTAS system two prize winning programs at the Turing test Loebner competition that we tested failed to exhibit comparable performance as shown by the dialog trace of the tests presented here.

1.Historical Introduction

Deduction is at the heart of Deductive Question Answering. Historically the formalization of deduction with natural language statements was first proposed by Aristotle with his theory of the Syllogism. Aristotle's theory of the Syllogism is based on an analysis for the first time in Human history of Human logical thinking. His definition of the syllogism is as follows:

"A syllogism is discourse in which, certain things being stated, something other than what is stated follows of necessity from their being so. I mean by the last phrase that they produce the consequence, and by this, that no further term is required from without in order to make the consequence necessary. I call that a perfect syllogism which needs nothing other than what has been stated to make plain what necessarily follows; a syllogism is imperfect, if it needs either one or more propositions, which are indeed the necessary consequences of the terms set down, but have not been expressly stated as premises." (The passage is reproduced as it was rendered in English by Steve Thomas for the University of Adelaide Library Electronic Texts Collection).In the above definition Aristotle defines the "syllogism" as a kind of logical reasoning based on the combination of natural language sentences.

This description laid the foundation for the mechanization of such reasoning that eventually leads to the automatic generation of the explanation of the steps followed in such reasoning.

It is remarkable that such a systematic discussion of logical information processing was achieved so early in Human history despite the lack of mechanical information processing that was however accomplished a few centuries later with the Greek Antikythera Mechanism [1,2,3]. The Antikythera Mechanism, dated between 150 to 100 BC, is the most sophisticated scientific instrument of the ancient world discovered until now. The mechanism is an astronomical special purpose "digital" mechanical computer of unprecedented complexity.

The digital nature of the Mechanism follows from the obvious fact that computations are performed using gears that have necessarily a finite number of teeth. It is also remarkable that an inscribed "manual" written in Ancient Greek was found as part of the Mechanism.

2.Machine Consciousness

The concept of Machine Consciousness, at least lexically, relates to the concept of Human Consciousness [4] and hence has created strong scientific controversies. Some scientists oppose strongly to the idea of such an artificial system that it is supposed to exhibit behavior that only living beings can do. My position is that there is nothing wrong in defining a category of Artificial Intelligence (AI) systems that display patterns of behavior **inspired** from the behavior of living conscious beings. One such pattern of behavior that we have implemented is the one of "reporting" the steps followed while performing some information processing. This reporting may be useful for explaining to the user of such a system why a specific answer is given to her question.

Machine or Artificial (as some call it) Consciousness is a new subfield of AI. This subfield emerged recently but it has developed rapidly having obtained since 2009 its own scientific journal with the same name which unfortunately ceased publication in 2014. Machine Consciousness (MC) research has at least two distinct goals:

A. Simulation of Human Consciousness mechanisms.

B. Implementation of computer systems for tasks requiring MC functions that are INSPIRED by Human Consciousness phenomena.

Goal A is unattainable at present because of basic scientific problems that remain unsolved for Human Consciousness namely:

1. There is no technology available yet to study Human Consciousness experimentally in detail. We must first discover the details of simple mental processes like counting from say 1 to 100 and then set such lofty goals as verifying detailed scientific theories about human consciousness.

2. There is no generally accepted theory of Human Consciousness yet partly due the lack of a technology for experimentally verifying such a theory [5].

3. New theories like in [6], [7] and [8] appeared even recently and wait to be experimentally evaluated.

Machine Consciousness (no matter how we name it) needs to be established as an engineering field only remotely related to the Psychology of Consciousness.

Engineering systems should be evaluated by their usefulness and not how they implement anybody's fantasies of how the brain works. One function of possible usefulness of an "Artificially Conscious" system is its reporting to its user the steps via which it generated a certain result of a computation. If such a report is found useful by the designer or the user of the system then neither Philosophy nor Psychology of Consciousness have much to do with it. A special case of MC is Machine Introspection of reasoning on which the generation of explanations of reasoning is based and which is analogous to “Human access consciousness” [9] .

“Self-aware systems” [10] and “Meta-cognitive systems” [11] and [12] are some of the early terms used before the terms “Machine Consciousness” (MC) and “Conscious Machines” were established [13] to [23]. Recent claims of the achievement of MC and its application are made in [24] and [25]. I have tried in my publications to avoid anthropomorphic terms like “Consciousness” and “Introspection” when referring to computer systems but with little success.

I have tried the term “Metagnostic” insinuating that some kind of meta-knowledge processing is involved but again the term “knowledge” sounds anthropomorphic. For this reason I propose now the hopefully less anthropomorphic term: “Autoendoscopic Computer Systems”.

Some computing tasks such a system may be useful for are:

1. *Information Extraction*
2. *Deductive question answering from texts*
3. *Computer aided instruction*
4. *Debugging software systems using explanations of their failures*
5. *Artificial vision based on image understanding by reasoning.*

A software system may be reporting on its operation in a human-friendly form generating one or more of the following indicative outputs:

1. The description of its own structure

2. The description of its present state

3. The state history of reaching its present state

4. An explanation summarizing its state history

5. The history and explanation of the compression of its input data

6. The history and explanation of some of its possibly erroneous performance

7. The history and explanation of its performance improvement

We have implemented software systems able to generate automatically user-friendly explanations of their answers when activated by a user’s question in order to display behavior analogous to the behavior of a conscious agent. My first implementation of a software system that used a natural language text as a knowledge base and which can perform deductive question answering and explanation generation using mainly causal reasoning was presented in 1992 generating output Nos 2,3 and 4 of the list above. I would now call such a computer system “autoendoscopic” in order to avoid more anthropomorphic terms.

3.Question Answering

Question Answering (QA) is a topic of Artificial Intelligence that in its simple form often called “the factoid task” was introduced in the sixties. Deductive Question Answering is a recent research trend of Artificial Intelligence. We may consider the above mentioned Aristotelian theory of the Syllogism as the precursor of Deductive Question Answering.

The classical Aristotelian syllogism example:

“Socrates is a man. All men are mortal. Therefore Socrates is mortal.”

may be viewed as proposing a deductive mechanism for answering the question: “Who is mortal?” given the text: “Socrates is a man. All men are mortal.”

QA systems accept questions in natural language and generate answers usually expressed in natural language. The answers may be derived from data bases, text bases or knowledge bases. The main aim of QA systems is to generate a short answer to a question rather than a list of possibly relevant documents as some do.

Deductive QA systems generate answers by the logical combination of facts retrieved from the bases that support them. In the case of text-based Deductive QA systems, two main kinds of texts are used namely narrative and expository texts.

We have implemented QA systems for both kinds of texts namely the PLASMA system for narrative texts and the AMYNTAS system for expository texts which is the one further described below.

4.Question Answering by Turing Test Candidate Programs

Alan Turing [26] proposed a test for Artificial Intelligence based on the dialog between a candidate system and human users. In 1990 H. Loebner agreed with The Cambridge Center for Behavioral Studies to underwrite a contest designed to implement the Turing Test. Dr. Loebner pledged a Grand Prize of $100,000 and a Gold Medal for the first computer program whose responses were indistinguishable from a human's. Such a computer program can be said "to think." Each year an annual cash prize and a bronze medal were awarded to the most human-like computer program. The winner of the annual contest was the best entry relative to other entries that year. Part of my dialogs with the 2012 and 2013 winners given below while the full dialogs are reproduced in our book [27].

My dialog with Chip Vivant

The 2012 Turing Centenary Loebner Prize competition took place on May 15th 2012 at the Bletchley Park Museum and the 1st Prize ($5,000) and the bronze medal were awarded to the computer system *Chip Vivant* by Mohan Embar. My full dialog record with the winner program that was held on August 2012 can be found at the internet location: http://www.chipvivant.com/2012/05/15/chip-vivant-wins-the-2012-loebner-prize-competition/ as well as in our book [27].

Some examples of my dialog with Chip Vivant on August 13, 2012 at 11:26 pm are given below. My input is typed in bold letters and my remarks typed here in slant letters post mortem.

Example 1:

-Do you know the difference between advice and observation?

-The difference is in size, shape, color and price.

My remark= the answer is incoherent

Example 2:

-Advice and observation have no size, shape, color and price.

-You are so negative just to annoy me, I know! Oh, what a fruitful conversation.

My remark= the answer is incoherent

Example 3:

-I am trying to find out if you know the difference between words.

-I suppose you are joking. And you can’t tell the difference between too different things :-)

My remark= the answer is incoherent

Example 4:

-What lesson did you like at school?

-At least, nobody is shooting in our schools. But from another point of view, our school is quite boring.

My remark= the answer is incoherent

Example 5:

-Name a lesson you have taken.

-You know, I'd really like to find out your opinion about the Loebner Prize!

My remark= the answer is incoherent

My dialog with Mitsuku

The Loebner Prize 2013 Competition took place in Ireland and the result was the award of the 1st Prize and the bronze medal to the program "*Mitsuku*" written by Briton Steve Worswick from England who won $4,000 (£2,500).

I (Human) held a dialog with Mitsuku in December 2013 submitting as much as possible the same input as with Chip Vivant. Part of my dialog with Mitsuku is given below with my remarks in slant:

Example 1

-Human: when did you last play 20 questions?

-Mitsuku: Ok let's play 20 questions.

My remark= the answer is incoherent.

-Human: you did not answer my question

-Mitsuku: OK. Please help me improve my communication skills. What would you have said?

My remark= apparently the answer is coherent.

-Human: when did you last play twenty questions?

-Mitsuku: Ok let's play 20 questions.

My remark= the answer is incoherent.

Example 2

-Human: What job you want to do?

-Mitsuku: A shopkeeper.

-Human: What job you want to do

-Mitsuku: A singer.

-Human: What job you want to do?

-Mitsuku: A butcher.

-Human: what job you want to do?

-Mitsuku: A singer.

My remark= the answers are inconsistent.

Example 3

-Human: you seem to change your mind too quickly

-Mitsuku: I always try to do things as quickly as I can.

My remark= the answer indicates lack of consciousness.

-Human: tell me the jobs that you chose

-Mitsuku: that you chose = Do you think I should know that?

-Human: yes

-Mitsuku: Aha.

My remark= the answers indicates lack of consciousness.

5.My conclusions from the Turing Tests

The most important conclusion from my experiments is that the 2012 and 2013 winners of the Loebner prize can easily be disclosed as non human as they display neither consciousness or sense of dialog coherence.

The questions appropriate for uncovering during a Turing Test a computer system should utilize some of the following human capabilities during the dialog with the judge that did not seem to be utilized, as far as I know, by the judges of the Loebner Prize competition:

1. *Sense of dialog coherence*
2. *Consciousness*
3. *Logical Reasoning*

4. *Memorization of and Learning from the Dialog*

5. *Humour appreciation*

6. *Irony appreciation*

7. *Metaphor Understanding*

I performed the above experiments during the 2012-2013 period. I was subsequently surprised to learn that in the 2014 test a program named "Eugene Goostman" succeeded to "pass" the test.

I have tried in vain several times to interact with Eugene Goostman but I found it inactive. Some scientists have criticized the Turing Text and have proposed a new test to replace the Turing test called the "Winograd Schema Challenge".

6.Deductive Question Answering from Texts

Deductive QA from texts uses a natural language corpus to derive its answers from. The traditional method of implementing such systems involves the translation of these texts to a formal language before executing any deduction. Some of my research work is based on the revolutionary hypothesis that the logical deductive processing of natural language texts by computer is possible without previous translation into a formal language. This idea of using deduction for QA directly from texts was presented in [28] for the first time.

It is commonly believed that in order to facilitate reasoning one should translate texts into a formal representation using an artificial language like symbolic logic. However the translation of natural language texts into a formal representation demands a consensus on the appropriate formal representation. This translation has faced difficulties in materializing due to the richness of expression achieved with the use of natural language.

Additionally natural language is continually evolving both lexically and semantically together with human knowledge and this means that scientific texts translated to a formal representation may have to be often retranslated. These considerations prompted me to ignore Frege's proposal and implement a system that answers questions and generates explanations directly from natural language scientific text.

My work reported in [29] concerns an implemented experimental system aiming at the application of my novel deduction method named ARISTA (Automatic Representation

Independent Syllogistic Text Analysis) that differs from the established formal language based methods. The basic difference of my method ARISTA from the established methods is that the text is used as a knowledge base and conclusions are produced by the deductive mechanism of the system without previous translation of the text into some formal language.

In addition an explanation of the system reasoning is generated automatically thus displaying behavior analogous to introspection based reporting.

A number of deductive Question Answering systems have been implemented by our group from 1991 to 2012 that have gradually exhibited increasing ability of reporting analogous to Human introspection based reporting.

Some of these systems are the successive versions of a computer system that we call "AMYNTAS" resulting from "Automatic Metagnostic YpologistikoN Trainable Answering System".

The behavior of the AMYNTAS system results in generating explanations of the computational process executed during text mining tasks. These explanations may be used for debugging the system. I have also proposed that the generation of explanations is the main way that the user of a computer system may be convinced that the system exhibits behavior analogous to Human Consciousness.

In my early effort [29] of "machine introspection" or "autoendoscopy" as I call it now I used as example a paragraph from a Physiology book describing the function of the human respiratory system. This was my first implementation of a software system that used a natural language text as a knowledge base for deductive question answering and explanation generation using mainly causal reasoning.

The work reported in [29], [30], [31] and [32] concerns an implemented experimental system aiming at the application of my novel deduction method named ARISTA (Automatic Representation Independent Syllogistic Text Analysis) that differs radically from the established formal language based methods. This work resulted in our AROMA system [31].

7.Our AMYNTAS system

Structure and Operation of our AMYNTAS system

The deductive question answering system AMYNTAS reported in [33], [34], [35], [36] and [37] was implemented in Prolog and consists of six modules implemented as separate programs totalling about 50 pages of Prolog code. These modules communicate through some temporary files that store intermediate results. The six modules are: the question processing module, the text pre-processing module, the ontology extraction module, the shallow parsing or text chunking module, the question answering module and the metagnostic processing module.

The question processing module extracts information from the input question. The information extracted is a list consisting of the entities mentioned in the question and the relation that connects them. For example in the question “what influences p53” the entities are the entity p53 and the “unknown” entity standing for the entity that is sought and the relation is “influence”.

The text pre-processing module represents each word of a sentence as a fact with three arguments the first being the word itself, the second being the identifier of the sentence and the third being the position of the word in the sentence counting from left to right.

The ontology extraction module locates linguistic patterns in the input text corpus that may be used to extract automatically meronymic and taxonomic knowledge that may be used at question answering time.

The shallow parsing or text chunking module locates a verb related to the relation contained in the question and extracts the two substrings of the text sentence being analyzed that appear to the left and the right of the verb and end at some stop-word or punctuation mark. The latest version of this module is based on a finite state automaton implementation.

The question answering module finds the answer to the question from the pre-processed text.

The question answering module accepts questions that potentially require the combination of facts with the use of prerequisite knowledge for answering them. The prerequisite knowledge available to our system includes ontological knowledge and synonyms of the named entities involved of the domain which are used in order to combine two or more facts mentioned in the text corpus using production rules.

The metagnostic processing module generates explanations of the operation of the system collected from the two modules namely the shallow parsing module and the question answering module that are operating as finite state automaton and as production system respectively. These three modules are the parts of the system that exhibit whatever machine consciousness could be expected from such a system. At question answering time three looping operations are taking place. The basic loop concerns the search for an entity in a chunk related to the relation of the question. The second loop concerns the transformation of the list obtained from the question by following a particular strategy from the explicit list given to the system. The third loop searches for chains of facts using the matching of named entities occurring in the right part of one fact and the left part of another fact.

Recent surveys [38],[39],[40],[41] do not mention anything similar to AMYNTAS.

Information Extraction from Protein Interaction Texts from Pubmed

Pubmed is a text base consisting of abstracts of biomedical research papers. Given a text fragment from PubMed to the question answering system [34] and [35] and given the question: “What influences p53” generates an answer “*p53 is influenced by p53”* and an explanation of this answer which means that a closed loop system is found to be described by the input text. This answer means that the causal relations recognized in the text fragment processed by the system form a closed loop.

Given the following text fragment from PubMed to our question answering system:

(1) “The p53 protein regulates the mdm2 gene”

(2) “The mdm2 gene enhances the tumorigenic potential of cells”

(3) “The mdm2 oncogene inhibits p53_mediated transactivation”

And given the question: “*What influences p53*” it generates the answer:

I found that the entity <p53> is one of the tokens of the chunk <the p53 protein>

which is the chunk to the left of the verb <regulates> of the sentence <1>.

I found that the chunk to the right of the verb <regulates> of the sentence <1>

is the chunk <the mdm2 gene > and since its first token is not an entity, I tested the rest of the tokens.

The entity <mdm2> is one of the tokens of the chunk <the mdm2 gene>

Which is the chunk to the right of the verb <regulates> of the sentence <1>.

I found that the entity <mdm2> is one of the tokens of the chunk <the mdm2 oncogene >

Which is the chunk to the left of the verb <inhibits> of the sentence <3>.

I found that the chunk to the right of the verb<inhibits> of the sentence <3>

is the chunk <p53 mediated transactivation > and

The entity <p53> is one of the tokens of the chunk <p53 mediated transactivation>

Hence It follows that <p53> is influenced by <p53>

The concluding answer given above means that the causal relations recognized in the text fragment processed by the system form a closed loop.

The System Evaluation

The performance of the system was evaluated using a set of 127 sentences obtained from the PubMed Data Base that were selected from the titles of papers. The criteria of selection were that they contain the name of the protein p53 and the influence verb "enhance". These 127 sentences are all that were found from PubMed on October the 7th 2008. This set constituted an input text to the system and was checked by the biologist Dr. Ourania Kosti.

The results of evaluation of the parsing module quantified in terms of "precision" and "recall" are:

Precision= 80% and Recall= 94 %,

where precision and recall were computed by the formulae:

Precision=

correct answers generated (True Positives) Divided by # total answers extracted (True Positives + False Positives)

Recall=

correct answers generated (True Positives) Divided by # total correct answers identified by the biologist (True Positives + False Negatives).

The flexibility of the system was evaluated by showing that it may very easily be adapted to completely different domains such as the proofs of Euclidean geometry, Ancient Greek History text and Image Anomaly Detection as described below. The only changes necessary were the enrichment of the lexicon and the ontology so that it includes the entities, the concepts and the relations of the new domain.

A Geometric Domain application of AMYNTAS

AMYNTAS was applied to Deductive QA in the geometric domain by computer in a way that is related to Machine Consciousness [33]. In the geometrical domain the system AMYNTAS is able to identify the sentences of the input text that logically justify a statement included in the English translation of the text of the proof of the first Proposition from Euclid's Elements. The answering of questions from the text of the proof of the first Proposition of the Elements is sketched below.

The prerequisite knowledge used involves various kinds such us Euclid's common notions, postulates and definitions.

The first Proposition of the Euclid's Elements as stated in English in [42] is:

"Construct an equilateral triangle on a given finite straight line".

The equilateral triangle ***abc*** is constructed by the points of intersection of two equal circles and their centres ***a*** and ***b*** where these centres lie on each others circumference and the points **a** and **b** are the two endpoints of the given finite straight line. The Euclid's Elements text includes a proof that the triangle constructed in this way is equilateral.

The text of this proof is used as a text base for answering deductively questions and generating explanations concerning the justification of statements present in the proof text. The meaning of the geometrical entities involved in this Proposition may be understood by using the diagram shown in the Figure above.

The two equal circles ***c1*** and ***c2*** with centres ***a*** and ***b*** both pass from each other's centre. The equilateral triangle is constructed by joining the two centres and one of the points of their intersection which is point c in this case. The entities involved in the question and the answer are the straight lines ab, ac and ***bc*** and their synonyms ***ba, ca*** and ***cb*** respectively.

Part of the text of the proof runs as follows:

- *Since the point **a** is the centre of the circle c1, **ac** is equal to **ab**.*
- *Since the point **b** is the centre of the circle c2, **bc** is equal to **ba**.*
- *But **ca** was also proved equal to **ab**;*
- *Therefore each of the straight lines **ca**, **cb** are equal to **ab**.*
- *Things which are equal to the same thing are also equal to each other.*
- *Therefore **ca** is also equal to **cb**.*

- *Therefore the three straight lines **ca, cb, ab** are equal to one another.*
- *Therefore the triangle **abc** is equilateral.*

Three illustrative questions are answered by the system by analyzing automatically the corresponding Euclidean proof as follows:

- *Question 1: "why is side ab equal to side ac?"*
- *Answer 1: "because they are radii of the same circle c1"*
- *Question 2: "why is side bc equal to side ab?"*
- *Answer 2: "because they are radii of the same circle c2"*
- *Question 3: "why is side ac equal to side bc?"*
- *Answer 3: "because each of ac and bc are equal to ab"*

These answers are only partial. The full answers contain explanations related to computer aided metacognitive instruction for which see [43], [44],[45],[46] and [47].

Other explanation systems are reported in [48 to 53].

Question Answering from an Ancient Greek History text with AMYNTAS

The text used in this application of AMYNTAS [36] is part of the description of the Marathon battle by Herodotus from where the following sentence is used as an example of an input string from which information must be extracted in order that a relevant question may be answered:

". . the first thing the commanders did and this was before they left the city was send Phidippides an Athenian who was a professional courier to Sparta with a message ."

The explanation of the analysis of the above sentence that is automatically generated by our AMYNTAS system is as follows:

THE VERB <left> IS FOUND

THE VERB <send> IS FOUND

BECAUSE THE VERB-REJECTOR <before> WAS FOUND TO THE LEFT OF THE VERB <left>

THE ENTITY <commanders> WAS FOUND TO THE LEFT OF THE VERB <send>

THE ENTITY <Phidippides> WAS FOUND TO THE RIGHT OF THE VERB <send>

THE INFORMATION EXTRACTED FROM THE SENTENCE IS:

<Commanders><send>Phidippidis>

The parsing done by the finite state automaton used for the analysis of such a sentence consists in locating a verb related to the relation contained in the question posed and extracting the two main constituent substrings of the sentence.

These substrings appear to the left and the right of the main verb and end at some stop-word or punctuation mark. More details of the analysis may be found in [16]. Some of the sentences are rejected if they fail the criteria posed and constitute the set of "anomalies". In the development presented in this paper an explanation of the rejection is generated.

Image Anomaly Detection

The detection of image anomalies is a subject of recent interest in the Artificial Vision community. Applications of Artificial Vision such as security and car driving need to be sensitive to the occurrence of unusual events that are recognized as "anomalies". In addition to recognition it is often useful to generate explanations of such anomalies that may result as answers to questions like "What is the anomaly in the input image?".

In works of Modern Art such as cubist paintings the representation of reality is intermixed with anomalies i.e. deviations from the realistic representation of objects. The cubist painter attempts to enhance the depiction of a scene with pictorial elements that result from the three dimensional structure of the objects of the scene. For instance a face seen from the front may include elements seen from its profile.

These additional elements constitute "anomalies" from the point of view of realistic depiction of scenes. The analysis of these anomalies may lead to the uncovering of rules governing the three dimensional perception of objects that are manipulated by the viewer. An example of anomaly detection by computer processing and automatic explanation generation from the partial logical representation of the painting of Pablo Picasso *Les Demoiselle's d'Avignon* was presented in by us in [27] and [37].

The objects constituting an image or scene are connected with relations further than simple adjacency such as being above or below, being inside or outside as well as properties connected with the point of viewing them qua three dimensional objects.

The FSA presented in [37] detects and explains an anomaly in the image of one of the two faces in the modern painting of Pablo Picasso *Les Demoiselle's d'Avignon.*

The two faces that demonstrate a face anomaly consist of the conflicting views of the eyes with the nose. More complex images may be checked for anomalies and explained demonstrating machine introspection. In order to obtain a representation of an input string to the FSA a segmentation of the image must first be performed.

It is presupposed that this segmentation is based on a horizontal raster scan of the image and the local recognition of the main components of a face namely eyes, nose and mouth together with the recognition of whether they are viewed from the front or from the side. XY coordinates are not needed in this case but an integer will specify the order that the segments are found during scanning.

A two-way generalization of a simple FSA was proposed in [37]. First the FSA has a vector state representation instead of the usual scalar representation which means that its state is represented by an n-tuple rather than a single symbol. Second the states of this FSA are annotated with explanation texts. In cases of qualitative reasoning and explanation of the detection of an image anomaly the representation is simplified by omitting the position coordinates.

The representation of the input as the segmented version of an anomalous face image is assumed to be in a list of Prolog facts form:

ob (eyeL, face, senseorgan, front,1). ob (eyeR, face, senseorgan, front,2).

ob (nose, face, senseorgan, side,3). ob (mouth, face, senseorgan, front,4).

Using the template "ob (name, part, kind, view,int)" where:

"Name" is the name of a segment.

"Part" is the larger structure that the segment is a part of.

"Kind" is the hypernym of the segment.

"Int" is an order specifying integer.

The transition table of the automaton of the vector state FSA for the processing of this example input consists of a list of quintuples of the form S1L, S1G, X, S2L, and S2G to which explanation texts are appended. These quintuples have the form:{S1L, S1G, X, S2L, S2G} S1L is the present state of the local part of the state vector.

S1G is the present state of the global part of the state vector

X is the present input object.

S2L is the next state of the local part of the state vector

S2G is the next state of the global part of the state vector

The possible values of the local part of each state are {1eye, 2eyes, nose, mouth}.

The possible values of the global part of each state are {front, side}.

The explanation generated for the anomaly of the example input is:

"I found 1eye with view from the front.

I found 2eyes with view from the front.

I found nose with view from the side.

THEREFORE

Anomaly found because the point of view of the nose is different from the point of view of the 2eyes"

This function of the AMYNTAS system is the generation of an explanation of its reasoning while detecting an anomaly in an input. The method is based on a vector state finite state automaton model for the parsing of the input data.

8.Machine Consciousness and Software Synthesis

Programmers understand less and less all the operation of their programs as their complexity rises above a certain level. This is really dangerous if these programs control critical infrastructure systems like air traffic control systems, power stations and energy grids but also systems like airplanes and trains.

It is urgent then that a new kind of software engineering be developed for the implementation of computer systems that "know themselves" and can give crucial answers to the "what if" and "why" questions of their users in cases of emergency or failure. Artificial Intelligence can be of help with methods resulting from the research results in the field of Machine Consciousness. Eventually software systems supporting debugging with explanations of their failures or anomalous behavior will be very useful. I propose that a software system must be able to generate automatically user-friendly explanations of its answers when activated by a user's question in order to display behavior analogous to the behavior of a conscious agent.

9.Conclusions

The present paper concerned our implementation of Machine Consciousness as a development of Deductive Question Answering from texts technology. It was described how our AMYNTAS Question Answering system generates in addition to an answer an explanatory report in natural language of the steps followed for the generation of answers. Given that our system is based either on finite state automata or on production systems I propose that these are two ways of implementing Machine Consciousness in the case of Deductive Question Answering from texts systems as pursued by our research.

One way is based on the state change path followed by an automaton and the other is based on the chain of productions activated during generating an answer.

Another conclusion from my QA experiments with the 2012 and 2013 winner programs of the Loebner prize contest can easily be disclosed as being non human as they display neither consciousness nor sense of dialog coherence.

Finally we conclude that Deductive Question Answering and Software Engineering technology may benefit from the application of Machine Consciousness techniques in various ways. This application has been already attempted for the first case but it has still to be investigated for the second case.

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