Semantical Case Based Reasoning related to
Virtual Doctor System (VDS)

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Abstract—Human computer Interaction based on emotional modelling and physical views, collectively; has been investigated and reported in this paper. Two types of ontology have been presented to formalize a patient state: mental ontology reflecting the patient mental behavior due to certain disorder and physical ontology reflecting the observed physical behavior exhibited through disorder. These two types of ontology have been mapped and aligned for reasoning using a simple Bayesian Network for causal reasoning to define what we call as simple case diagnosis. We have constructed an integrated computerized model which reflects a human diagnostician as computer model and through it; an integrated interaction between that model and the real human user (patient) is utilized for 1st stage diagnosis purposes.

Keywords—Medical diagnosis, knowledge based reasoning, cognitive model, human interaction

I. INTRODUCTION

This paper discuss issue on using a real case study to examine semantic Case Based reasoning (CBR), related medical diagnosis based scenarios provided by medical doctors. We have constructed a system as virtual medical doctor (VDS) avatar that resemble a real human doctor and act to interact with patient user to establish a diagnosis scenarios based on patient interactive procedural routine. The system outline is shown on Fig.1.

We have created a related technology, reflecting the state of art on creating a program that resembles the user mental psychological behavior through a face, this concept we called it mental cloning [1]. The mental cloning is used to collect the built avatar reflecting a real person, the animated real-time images created in real-time on this avatar resembling the emotional behavior of that person reflected through this avatar in the same manner the real person interact with certain world in similar invocation. This is represented by using that person ego state [3][10].

In this paper the system is expanded to resemble a medical doctor that interacts with human patient for medical diagnosis. The interoperability represented by utilizing the medical diagnosis of medical doctor in machine executable fashion based on patient interaction with virtual avatar resembling a real doctor. The Virtual Doctor System (VDS) is installed in a local hospital in Morioka (Iwate-Japan) where that doctor is regularly, practicing her medical diagnosis in real situation and environment. The avatar or VDS is working as a 1st glance diagnosis to classify patient based on the criticality and emergence based on examination parameters and diagnosis scenarios.

The VDS we constructed is a type of MDSS (Medical Diagnostic Decision Support Systems) based on cognitive interaction, (taking into account cognitive interpretation of patient emotions). MDSS [20] is valuable aid in improving the accuracy of medical diagnosis. Medical errors are crucial problems in health system [21]. Our system can participate to enhance the medical service reliability and robustness, by providing bootstrapping techniques on simple case diagnosis, related to case based reasoning, medical cases provided by the MDs, and represented in our approach presented in this paper. Mental reasoning is essential in understanding human behavior. Having the system learn on user behavior is one issue that we need to understand. Hebbian learning has been used in [22] mirroring of body states of the observed person within the observing person. This approach [22] is based on Hebbian learning that to define explicit properties and states of the mental model in predictable manner. In VDS the explicit reasoning on patient states (physical and mental) should be articulated on reflected issues in medical knowledge. This approach [38] does not take into account the interaction as part of the problem as we do in our approach. Also, other [23][24] approaching, like Shared circuit model is lacking efficient interaction mechanism reflected in the cognitive mirroring concepts. Variable expression of individual patients may have different partially overlapping combinations if symptoms and clinical sign. A timely correct diagnosis is important. Explicit ranking of the diagnosis procedure are not appropriately available [24].

We think our solution participates in better approaches to solve these issues. We need to provide ontology for ranking diagnosis in appropriate manner such that to articulate it in appropriate manner to the individual patients.

We also, are extending the VDS application to internet based service, so that patient can utilize it before attending the hospital through mobile technologies. This is to be reported in the future.
II. VDS OUTLINE

These issues outline above are the subject of this paper. Medical scenarios are defined on general guidelines formalization, and customization according to the subject doctor experience and related specialization on the course of medical practices. The system is to help the real doctor by filtering the outpatient (when they come to the hospital) who waiting to see the real doctor.

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The simple case treatment is in most cases is to ask the patient to rest and come back after few days if the recovery is not achieved or correlated physical (body) phenomenal sign is emerged, or stayed (not relieved). We have selected the simple case approach due to the following: We can test our system and its reasoning design framework. We use the system for helping the medical doctor to classify medical cases for outpatient based on criticality issues. Criticality issues are estimation of the outpatient sickness state. This is based on his/her mental and physical reasoning that is achieved (i.e., reached) collectively (inferred) by the VDS. The system outlined in this paper is structured as, Sec. 2

Fig. 1: System outline

doctor experience and related specialization on the course of medical practices. The system is to help the real doctor by filtering the outpatient (when they come to the hospital) who waiting to see the real doctor. The virtual doctor sees patients by interacting with them and issues a decision making for simple cases and non-simple cases categorical analysis. The simple medical case in our context; is defined as the case that usually medical doctor reaches through medical diagnosis, such case is considered by medical Doctor namely A, as a state that the outpatient can be recovered by taking a rest, or simple medical supplement, a case resulted from stress, heavy work or tiredness. The
select the best scenarios that would be readout to the patient in the same manner as the real doctor does. On [10] we appended several video that demonstrate how the VDS interact with the patient and how the system’s camera eyeing on patient face to extract values (related to observed symptoms) to reason through on patient state. http://www.somet.soft.iwate-pu.ac.jp/system_news/ has some demo files available for download.

III. REASONING FRAMEWORK

There are several parts related to the VDS interaction parts that have already reported in published work related to voice face emotional recognition based on extracting ego state of the patient [4][5] and voice emotional recognition [6][13]. We have built a concept we call it as mental cloning [1] we could collect user emotion and mentality reflected through face and voice to understand the mental state (ego state) of the user. These are used for creating output for the avatar and input data due to user emotional change (engagement) with the avatar [2]. We have restricted our diagnosis reported in this paper to simple cases. The context of the engagement is defined in advance (In this paper the context is medical diagnosis based on Doctor A). So collecting the user mental state is to have the system adapt to changes that would have the user be engaged with the system in a positive manner (forwarding interactive style of communication).

The avatar in our system that we built as experiential is virtually constructed to resemble real Doctor or person who is the object the patient use to interact. We have a mask face model for real doctor practicing his/her medical provision in hospital in our town [2][1]. Such face will interact with the user in emotional based manner [10]. The face would smile or else and act in emotional manner according to the context and engagement style of the user. The face mental background resembles an ego state reflected through the egogram resembled person (medical doctor) represented in the system as a program [10]. We have studied this aspect and we created a program that can interact with the user using transactional analysis [3]. The face states are the primitive states that the system would select interactively according to the user engagement cognitive state (shown in Fig.3). The user ego state is also collected from the best match from the database based on what we called universal template. A set of egograms is stored in the system and indexed according to universal templates [3]. We have evaluated these universal template based on experimenting them with Miyazawa Kenji avatar that experimented in A museum [10]. These stored classified ego gram are to work as a templates to test user ego states (emotion). User observed ego state is measured through a set of universal templates. The measurement of face parts movements (eg. eyebrows, mouth as shown on Fig. 4) are referenced (computed) to a indexed templates collected from many Japanese subject (people) contributed
in our experiment [3][5][6][10]. On [10] you can view (download to view) the movies showing how the system works and also for public news on the project, (in Japanese media).

The system would test the mental states of the user based on these ego grams, and interact with the user based on instantiation of observed changes on the face parts collected due to emotional reasoning based engagement. Also, the same is done on the voice as well. The voice emotional features are examined to reflect the patient voice sound features like soaring throat related sound feature (based on sound pitch and power classification), or related expression to pain or else. The same also, is for expressing the dialogue with patient by doctors with emotional voice to patient synchronized with their mental situation.

However, we have not presented patient voice emotional recognition or VDS generated emotional readout diagnosis in this paper.

Taken all these technologies into account we have examined, and experimented reasoning related aspects reflected to medical use-case provided by two medical doctors in our city. We have built the system that ensemble a medical doctor interacting with the patient based on the established technology simply outlined above, to do diagnosis on patient at clinic or hospital in our city, Japan. The system is working as a filter (sorter) to do the 1st diagnosis based on provided medical guidelines specialized on these two nominated medical doctors working in the hospitals. This is especially useful in Japanese local hospitals when patient usually waits for one to two hours to see the doctor (human physician). The system would assist the hospital to set patients into simple cases, (without real physical observation) and non-simple cases, (need real doctor observation).

The main issue that reported in this paper are related to new findings that we have collected in relation to VDS is using the mental cloning concept and the avatar technology together to construct a copy of medical doctor avatar [8][9].

We have experimented two types of medical doctors. MD_A and MDr_B who are working in two different hospitals in Japan. These two hospitals' doctors' avatars are constructed. The avatar face and voice with related diagnosis scenarios on “simple cases” have constructed. We have selected these two doctors based on the style of their diagnosis. MD_B uses patient appearance in reasoning and diagnosis (with certain physical touch), while MD_A uses egogram based certification to analyze the patient mental states and do diagnosis on patients' condition by navigating in these states, through specific scenarios and networked style of decision making. MD_A integrates all these decision based on her experience, represented as decision network style. These two instances of MD style of reasoning (diagnosis) are examined and represented in the VDS system presented in this based on provided instances of simple cases medical practices data.

A. Simple Case

We define what is the simple case, and what are the formal guidelines defining the simple case (Fig. 5). The relative customization of such simple cases due to the doctor experiences in diagnosis. It is those cases that the MD concludes them as not critical symptoms, or symptoms that may need later on further observation, or situation that is not necessarily be recovered by medication or surgery or else. A relative medical advice, or supplementary medication supporting the medical case in hand, or/and appointment to come again to confirm the sustainability of such case, are to be provided as MD for these called simple case based CBR.

B. Conceptual Reasoning Based on the ontology

The conceptual reasoning framework is based on presenting two types of ontologies, reflecting patient (user) physical conceptual status as seen by the VDS, as shown in Fig. 5. We have used a combination of probabilistic techniques, ontology representation and inference to determine the simple case we defined in our context. The target of the system is identifying the patient case as simple, with weight. (Simple_?), where? is: High, medium and low, or not-simple. The decision of taken as “not simple” means to go to the next room to see the real doctor. The related technical reasoning is also sent to the real doctor.

We have defined two types of ontologies (as shown in Fig.2).

Physical Ontology definition: PhO.

Mental Ontology Definition: MeO.

Each ontology represents causal relation articulated from physical view analysis, and mental view analysis.

This is shown in Fig.6. and Fig.7.

Probabilistic model has been used to reference and infer to doctor diagnosis. This part is taking use of alignment of the two defined ontologies, and do diagnosis based on probabilistic calculation to compute values that would be used to make the decision related to special cases, this is modeled on Bayesian network.

Values represented as Meta model by the PhO and MeO, as types reflecting collected data from patient observation.

Ontology alignment is very challengeable problem and active research in ontology engineering [7].

Inference uses the Bayesian network (as belief network) aligned and reflected on these two ontologies. On Fig. 5 we can see the big arrow at the left side. This arrow is reflecting to collecting data through the user interface to articulate in collective manner the PhO issue, aligned with the MeO.

User situation classify the meaning of metadata based on (gender, egogram, age, history) [2]. The situations are represented by [gender, age, egogram] These are variables, acting as values that in a collective manner classify the medical scenarios of the mentioned two types of nominated Doctors examples. These values articulate to diagnosis in probabilistic manner to reflect the aligned mental view and
physical view. The both are aligned to articulate on status of the outpatient in probabilistic manner to reason through on probabilistic combination of symptoms modeled as belief networks that is used to find the related remedy. The system shown in Fig. 1, there are example on probabilistic causal reasoning through Medical doctor approximation to treat the patient case.

The history is defined based on last state of the patient state. If the last state is simple, then we carried on. If not simple then continue with extracting data and send these to real doctor, for real-diagnosis.

The variables are those values defined by the PhO and MeO views. These variables are any values among 0 and 1. These values are representing the temperature in relation to threshold values (representing normal situation articulated on user situation). The total weight total of these values should be one.

Symptoms type Physical: Are those symptoms observed on the patient by devices or previous documented data (Fig. 5). In our system, we have the patient be seated on a chair with three types of devices that read: The body weight, temperature distribution on the face, and blood pressure. There are also other data that can be collected from previous history or document, referencing to previous physical state and articulate the new state.

Symptoms type Mental: These are the observed behavioral patterns on the patient face, articulated through templates to reflect the mental state of the patient, if she/he is in a pain or a sort of situation. These are classified according to the ontologies and as shown on Fig. 6 and Fig. 7.

These above two situations each are reflected and represented on ontology reflecting the medical ontology specified by the two medical doctors and specialized by the difference in their ontology in patient diagnosis.
The Symptoms reflected on Physical ontology are those reflected on mental ontology are mutually independent. The medical ontology represents the conceptual (abstract) view of medical diagnosis. The view is specialized by the doctor type, reflected as a model speciation, on the usage of the PhO and MeO in diagnosis. The simple case is defined in conceptual view and generalized form, the specialization due to the type definition of simple cases according to the doctor experiences is represented by on medical ontology. The style of reasoning diagnosis is also relative to the doctor diagnosis ontology (as a specialization to medical ontology).

The variables outcome would infer to the medical cases and invoke certain scenarios. These scenarios are explained to the outpatient as question or comments, expressed by the VDS in the same manner the real doctor does.

All variables values are computed based on mental and physical observation in the model. Variables are computed and collected by initiating scenarios with outpatient to collect these causes’ values (probabilistic) for decision making.

With the medical doctors help we have established several cases resembling different types of configuration of variables. These configurations can resemble different types of simple cases. We could create more complicated configuration in the same manner, however this would make the Bayesian network more complicated. However, at the moment our interest is to build the system and test it in these two hospitals. There are several issues that need to examine from real experiment. Not only the inference complexity, but the practicality on having such system in medical practices for simple case scenarios needs to be investigated.

The probability weight of each symptom is calculated with weights representing the importance of that variable. All variables in the PhO, MeO have classified weight reflecting the structure of medical knowledge. The knowledge base of medical knowledge is categorized and classified base on these variables importance as part of the two defined ontologies. The evaluation is not numerical but subjectively qualitative and oracle.

We have created an evaluation as 30 outpatients, diagnoses were done by the system: 20 patients participated in the experiment: 5 simple diagnosed by the system among 20. The true Doctor diagnoses were 8 simple (the above 5 are included). Our doctors were happy on this result as is helping them to filter the patient cases. We can compute the system validity. Define to refine the simple case related issues through the two presented ontologies. This is to have MeO, be mapped with related aspect collected from the input to related aspect from the PhO, these two aligned and mapped on MedO which will align and map these two ontologies on medical (ontology) to specify and map (alignment) between the above two ontologies through causal relation based on Bayesian Network which is proved to be useful in reasoning on imperfect knowledge like these related to medical diagnosis on patient, with imperfect knowledge.

The result would produce a keyword (or a set of data) or a statement as query that infer through the reasoner for the related scenarios that can reflect a nest of related constraints. The medical alignment ontology is a conceptual view of simple medical case. The simple case is defined in conceptual view and generalized form, the specialization due to the type definition of different definition o simple cases due to the doctor experiences is represented by the simple medical case ontology. The style of reasoning diagnosis is also relative to the doctor diagnosis ontology.

A Bayesian network is a graphical model for probabilistic relationships among a set of variables represented using a directed acyclic graph (DAG), that arrows represent causal influence among its nodes. The
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Noisy-OR network has the assumption that the model makes is of causal independence among the modeled causes and their common effect. The word noisy reflects that the interaction among the causes and the effect is not deterministic, so it is not possible to capture all the possible causes of an effect.

We have used Netica[14] to construct the BN. Netica allows network construction and parameter learning from data. We derived the parameters for conditional probability values from medical studies related to simple cases observations. We have used causal independence model. As in the following section:

This based on causal independence need to facilitate through the conditional probability theory \( P(A_i \mid f(A_i)) \).

A diagnosis is instantiated from physical variables, \((ph_1, ph_2, \ldots, ph_n)\) and mental variables \((me_1, me_2, \ldots, me_n)\). These variables are mutually independent. There are also effect that articulated from each variables reflected from corresponding ontology, and all the summation of these effect would lead to medical scenario conclusion, the medical scenario is also can lead to other set of physical and mental variables and also lead to other medical it is an integrative causal reasoning based on Bayesian network.

\[
P[(med(a) \mid me_1, me_2, \ldots, ph_1, \ldots, ph_n)] = \sum_{i} P(med(a) \mid me) \prod_{i} P(e_{i} \mid me) \prod_{i} P(E_{i} \mid ph_i)
\]

where \(Ef\) or \(EF\) are Boolean value as either true or False mapped to the Med(a). Also these \(ef(i)\) and \(Ef(i)\) are conditionally independence between the both, as the signs (symptoms) resulted from the physical effect and mental effect together due to certain disorder. These are not necessarily correlated by their relation on the medical diagnosis reflected in the above formula that can establish decision making for causal reasoning on diagnosis. For example, mild blood pressure, with high_mild disgust, could lead to mild stress.

It is a type of Simple case as reflected from MDr. Saitou. We have noticed that; this is a sort of belief network for a noisy-OR type causal reasoning in context-specific independence [11]. The noisy-OR \((ef(i))\) is like a regular OR function, all its parents are binary values in \([0,1]\). As we have the PhO and MeO symptoms related nodes are causal independence related to ef(i), therefore, \(P[(med(a) \mid me_1, me_2, \ldots, ph_1, \ldots, ph_n)]\) is represented by terms of noisy hidden variables ef(i). Therefore we can calculate the conditional probability of all states reflected in Fig.8 example. The nodes in Fig.9, believe networks concept based on the aligned ontology are of two types: discrete nodes representing either symptoms observable or not. It is a binary value. There is continuous node representing values like temperature or weight (i.e., PhO), and these values are represented as conditional probability distribution. In other words, the temperature, for example is converted in high in relation to symptoms or low. This is possible by storing conditional mean and variance in each decision node namely the MeO \((i)\) and phO\((i)\).

Fig.2. resembles the type of reasoning to the simple case causal based reasoning. The causal network calculates to reach the appropriate decision through the different dataset provided by these two doctors.

There are ontology templates related to simple cases scenario. These are related to symptoms reading and can assign values to these templates for inference based on simple CBR.

There are concepts modeled in ABOX and the instances of Simple CBR are in TBOX.

The CBR is semantically based range of values related to provide instances to the templates as specialization. Collected values would compute the distances between different templates related to simple case scenarios cases.

Pattern classification related to different symptoms situations reflected on these ontologies is needed to be investigated for best models, as the one presented above. It is a type of supervised CBR, as it instantiates values assignment (with weighted clusters) on decision templates reflected on these two ontologies decision models.

Figure 7: Shows an example of belief network

Figure 8: The Bayesian network general concept
The analysis using the above formula is to calculate the probability of medical diagnosis based on collecting the effect (ef(i)) collected from MeO and (Ef(i) reflected from PhO), respectively as shown on Fig.2. The collected computed probability will be according to threshold values specify the patient as either simple case or not. For simple case, the system would advise the patient on his/her condition using a set of Simple cases categorized scenarios organized due to the physical and mental data. For example; temperature combination values (PhO) and disgust values (MeO). The conclusion will be presented to the patient as readout scenarios in the same manner as the real doctor does. For any other case, concluded as not simple the system may advise the patient to move to the next door to see the real doctor. The diagnosis scenarios and copy of it will be transferred as a file to the real doctor’s computer.

We have used Netica application [14] to build the Bayesian network reasoning engine. In addition, we use Netica Java application (API) to do the application that interact and reason on values for diagnosis pipelined with the OWL reasoning engine.. The implementation has done using JAVA with Netica connected with Jess reasoner. The program resembling the two ontologies based inference (Fig.8) build the Bayesian Network in the memory for decision making and reflect this in the reasoner such that to have the diagnosis processor (Fig.1) to select the appropriate scenarios according to Medical doctor position participating in the analysis.

Fig. 8 shows an example on how to use Netica to have the network learn the case data to do decision making based on samples collected from patient reading. In Fig. 7: The decision nodes specifying the user situation (age, gender), which is connected to continuous node that select the appropriate range of blood pressure (for example) according to age, due to provided tables that is reflected in these continuous node. The same is also valid for temperature. The belief network for pain (as Fig. 8 example), is ranged values combination from 6 emotional primitives that are articulated (due to age and gender) to reflect the emotional status of pain in belief network using Netica.

The knowledge bases are specified due to CBR categorization of simple medical cases into cluster related to hierarchy classification. We use to have K-Means clustering for this purpose to do clustering based on categorical analysis of CBR related to simple cases. The observed symptoms are applied to the related for reasoning and inferred to these clusters. This type of K-means classification based reasoning is a sort of categorical type of inference. At each category or k-means level we have internal classification based on Euclidian classification of related cases. The Euclidian type of reasoning infers to collected symptoms on specific CBR related to a specified selected category computed by K-means selection criteria. The inference is based on similarity computation. Similarity measure based on K-means clustering at the two ontologies, namely MeO and PhO, and is computed to measure the relationship between symptoms reflected on these two types of ontology. There is a joined similarity reflected on physical and mental similarities to determine the similarity between CBR medical cases. The information related to tune a related CBR according to the observed symptoms reflected through the function pretending to these two ontologies and are stored as configuration function reflected on MeO. The system reasons on MeO to collect and extract methods and parameters related to diagnosis scenarios.

Fig. 9: The mobile service provider based on VDS

As this research is a joint work with KDDI-Japan we are expanding it to provide a service that patient can use before attending the hospital where MD_A is working. The spotting of patient location can be done by simple API call based on cell phone and ID WiFi MAC addresses as the case in iPhone for location application detection. According to the GEOlocation API specification [25] we can allocate the patient location and also the related hospital that can fit to his symptoms or to his/her selection preferences. This specification is limited to providing a scripting API for retrieving geographic position information associated with a hosting device [25] as shown in Fig. 9.

The Mobile Web Initiative with such medical service to answer a growing need to enable more end users to utilize the web through mobile devices.KDDI-SNS(Social Network Services) [25] is one example on these initiatives that has used JIBE http://twitter.com/JIBE as integrated service provider in their smart phone. The user profile can be expanded to hold medical data and preferences of patients in the same manner as face book dictionary. User collected symptoms statues, patient location and situation preferences and other data are all collected to be viewed and articulated to the assigned VDS near by the patient location (detected by patient invariants defined in the system by the PhO and MeO, as well as the patient situation (location and etc.).
The collected data is sent and accordingly articulated based on medical preference related to MD_A or the hospital or the institutions that the patient location and other symptoms preferences are collectively used to define which hospital and what medical doctor is available right now. The mobile phone collects initial medical data on patients upon request by invoking a service, then the negotiation protocol as SNS is used to do interaction between the system at KDDI center related to hospitals and institutions VDS systems that the patient is aware on and near to his/her location or else. The system at KDDI sent all information to the hospital where MD_A is working and does diagnosis based on simple case detection scenarios explain in this above. If non-simple case is detected, then the SNS through KDDI center assigns patient to a queue at the hospital and to provide status report on the patient. If the patient is report as simple case, then the hospital is also reported on this and a caution will be taken to monitor patient status according to the guidelines provided by MD_A related CBR based VDS.

We have tested the system in one hospital where Dr. Saitou is working. The system could conclude simple cases based on Dr. Saitou provided case data. However, there are some problems that are majorly not technical and related to patient education to use such system. We found this is major obstacles however, this is not related to the technical aspect of the work. Combining the both ontology in classifying medical data and related diagnosis as a representation, and use that representation to built belief network to learn on decision making using the Medical doctor experience, all these are unique characteristics of this work. To have a dataset on simple cases and these dataset be used to set the decision making based on the two provided ontology in medical application domain.

Mobile integration Services

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