A novel Trust Evaluation Method for Ubiquitous Healthcare based on Cloud Computational Theory

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Abstract— **The notion of trust is considered to be the cornerstone on patient-psychiatrist relationship. Thus, a trustfully background is fundamental requirement for provision of effective Ubiquitous Healthcare (UH) service. In this paper, the issue of Trust Evaluation of UH Providers when register UH environment is addressed. For that purpose a novel trust evaluation method is proposed, based on cloud theory, exploiting User Profile attributes. This theory mimics human thinking, regarding trust evaluation and captures fuzziness and randomness of this uncertain reasoning. Two case studies are investigated through simulation in MATLAB software, in order to verify the effectiveness of this novel method.**

I. Introduction

Nowadays, anxiety and other mental disorders affect the 30% of population, especially in countries of west world [1]. Patients facing mental disorders cannot live a normal and productive life. For that purpose, in compliance with patient-centric model, modern psychiatric domain becomes ubiquitous and personalized . Namely, psychiatric healthcare services are provided within a Ubiquitous Healthcare (UH) environment without spatial and temporal limitations [1, 2, 3].Within that context, personalization concept can be approached from the perspective of selection of the appropriate UH Provider that accomplishes each patient's requirements as these expressed in his/her User Profile [3].

Regarding psychiatric domain, the notion of "trust" is considered to be the cornerstone for the establishment of effective relationship between patient and psychiatrist [2]. Essentially, the patient needs to feel secure that the psychiatrist is capable to assist him/her. Given a trustfully background, patient is complaisant to reveal his/her personal information, which is prerequisite for the provision of psychiatric healthcare services [2, 4]. In open and distributed environments, such as UH, the adoption of trust concept reduces the uncertainty that these environments inherit [4, 5]. Within that context, trust declares UH Providers willingness to provide reliable UH services [4,6]. From that perspective, effective UH service provisioning can be accomplished mainly because of trust bonds between members of UH environment, i.e. users (patients) and UH Providers [7]. Trust Management System (TMS) is the required background for the materialization of that concept.

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TMS analyzes competence and honesty related evidences with the scope of establishment and finish of interactions in terms of trustworthiness [8]. Yuan et. al. highlight through different scenarios the importance of trust in UH environment [6]. Recent literature reports a number of TMS designed for UH environment [5, 7]. Each TMS utilizes a different mathematical theory for dynamically evaluating generic behavior of UH Providers. This procedure is denoted Trust Evaluation and produces a number called Trust Value (TV) which is an indicator of each UH Provider's trustworthiness. In [9], a probabilistic TMS has been designed for UH environment that assesses UH Providers trustworthiness. Based on TV, TMS suggests to patient trustworthy UH Providers for interaction. Boukerche et al. argue that the exponential probabilistic TMS best meets challenges of UH environment [10]. In [11], a community-based TMS is proposed, where trust is approached as time variable magnitude. Finally, in [12] the concept of TMS is deployed on a opportunistic pervasive healthcare system. In that case, Trust Evaluation is performed by patients, depending on their experience with the healthcare system and TV are stored into dedicated modules

It is important to notice that TMSs designed for UH do not evaluate the trustworthiness of new registered UH Providers. Practically, TMSs assign a standard TV to all new registered UH Providers, irrespectively to their capabilities [5]. However, this approach is quite unfair because new-registered UH Providers have limited chances to be suggested for UH service provisioning. This paper deals with that issue by proposing a User Profile based Trust Evaluation method that exploits cloud theory. The proposed method predicts UH Providers' generic behavior, in terms of trustworthiness and assigns them a TV complying to their User Profile attributes. This novel method is based on cloud theory because it mimics human thinking regarding evaluation and captures randomness and fuzziness that the uncertain reasoning of Trust Evaluation inherits.

II. The Trust Management Concept within UH environment

In [2], a UH environment is designed for psychiatric domain, wherein a TMS is deployed for discovery and selection of trustworthy UH Providers for each patient UH service request [4, 13]. The given TMS takes into consideration a) patient's requirements as declare at his/her User Profile and b) different UH Providers trustworthiness as indicated through their corresponding trust values (TVs). TV is defined within the range [0, 1] and characterizes each UH Provider reliability on UH service provision. TVs greater

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than 0.5 correspond to trustworthy UH Providers, while TVs less than 0.5 indicate untrustworthy UH Providers. UH environment keeps two Central Lists, i.e. Trust List and Untrust List, for storing of UH Providers' TVs. A trust evaluation process occurs for every new-registered UH Provider in order a TV to be generated. A different trust evaluation process updates the produced TV after each UH Provider interaction with a patient.

TMS performs a Trust Decision Making procedure for selecting trustworthy UH Providers for any given UH service request. For that purpose, three trust information sources are utilized: a) patient's "Personal Interaction Experience", i.e. patient's opinion regarding the trustworthiness of UH Provider(s) that he/she has interacted with, in the past (if exists), b) "Reputation", i.e. accumulated opinion of other's active user's of UH environment and c) "Recommendation", i.e. aggregated opinion of distinct UH Providers [4]. In sense, each trust information source is a list with IDs indicating UH Providers and their corresponding TVs. TMS is responsible to combine the three information sources in order to produce a ranking of UH Providers that UH environment suggests for interaction. This is accomplished through a weighted aggregation of these trust information sources, where the weight depends on requestor's interaction experience with UH environment [13]. Sequentially, the produced ranking of UH providers is filtered by Central Untrust List in order to untrustworthy UH Providers be excluded. Subsequently, the emerged ranking is compared with Trust List for exclusion of the unavailable UH Providers. The final ranking includes IDs of all available and reliable UH Providers with their corresponding TVs. The UH Provider with the highest TV is selected for offering the requested UH service. In case that the final ranking has no records, i.e. none from the proposed UH Provider is available, TMS recommends a newly entered UH Provider with the highest TV. In that way, newly registered UH Providers have the chance to establish interaction relationships within UH environment.

III. PROPOSED CLOUD-BASED TRUST EVALUATION METHOD

In this paper the issue UH Providers' evaluation in terms of trustworthiness, when registering in UH environment, is addressed. The proposed method utilizes User Profile attributes and it is materialized through cloud theory because that mathematical approach mimics human thinking regarding evaluation process.

A. Cloud Computational Theory

Cloud is a novel theory that combines conventional fuzzy sets and probabilistic theory [14]. Cloud theory provides a mapping model between qualitive concept and its quantitative representation, taking also into consideration fuzziness and randomness that such an uncertain transition inherits [15]. Consider set U as a quantitative numerical universe of discourse and C as a qualitative concept in U. If element $x \in U$ there is a certainty degree $\mu(x) \in [0,1]$ that x represents qualitative concept C, i.e. $\mu(x): U \rightarrow [0,1]$, $\forall x \in U, \quad x \rightarrow \mu(x)$. The certainty degree $\mu(x)$ is a

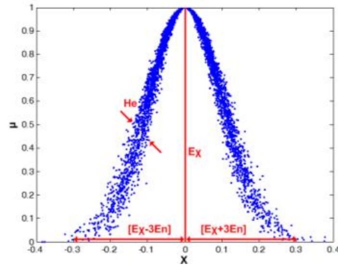

Figure 1. One Dimensional Cloud with (Ex, En, He) = (0, 0.1, 0.01)

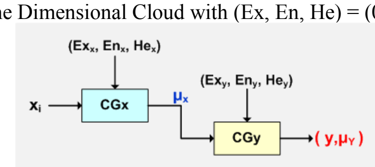

Figure 2. Implementation of a typical inference rule on Cloud theory

TABLE I. ALGORITHMS OF CLOUD GENERATORS

Algorithm	Cloud Generators	
	Forward CG	***Backward CG^{-1}***
Step 1	Generate intermediate variable $En_i^{'} \sim N(En, He^2)$	$Ex = \frac{1}{n}\sum_{i=1}^{n} x_i$
Step 2	Generate $x_i \sim N(Ex, En_i^{'2})$	$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - Ex)^2$
Step 3	Compute $\mu_i = \exp[-\frac{(x_i - Ex)^2}{2En_i^{'2}}]$ where (x_i, μ_i) constitutes a cloud drop	$En = \sqrt{\frac{\pi}{2}}\frac{1}{n}\sum_{i=1}^{n}\lvert x_i - Ex \rvert$
Step 4	Repeat steps 1-3 n times for generation of n cloud drops	$He = \sqrt{S^2 - \quad En^2}$

random number with stable tendency. The distribution of x on U is defined as "cloud" and expressed by $C(x)$ and each x is called "cloud drop". Cloud is described by expectation Ex, entropy En and hyper-entropy He [14, 15]. Particularly, Ex indicates the most representing value in U for C. Essentially, cloud's gravity center occurs at $x = Ex$, where $\mu(x) = 1$. En is a measure of C fuzziness and determines uncertain margins of C. Specifically, the 99.74% of cloud drops representing the cloud are contained within $[Ex - 3En, Ex + 3En]$. Finally, He determines the dispersion of cloud drops and it expresses the fuzziness and randomness of En.

Table I represents Forward Cloud Generator (CG) algorithm that produces cloud drops, given a cloud *(Ex , En , He).*Respectively, Backward Cloud Generator (CG^{-1}) algorithm computes (Ex , En , He), from a finite number (n) of cloud drops (x_i, μ_i), as shown in Table I. Conditional CG (i.e. generation of cloud drops given x or μ) is utilized for uncertainty reasoning [15]. Cascading conditional CGs materialize the typical qualitative inference rule "IF x is A THEN y is B" As shown in Fig. 2, a x-conditional CG implements the antecedent part of rule (IF) for generating μ_i i.e. activation degree of the given qualitative rule (x is A). Sequentially, a μ-conditional CG materializes the consequent part of rule. (THEN) by randomly generating a set of cloud drops (y_i, μ_i). In case of multiple-inputs-single-output qualitative inference rules (e.g. IF x_1 is A AND x_2 is B THEN y is C) multi-dimensional conditional CGs are utilized for uncertain reasoning [14]. In a system of qualitative inference rules, the consequents are geometrically accumulated through a CG^{-1} for generation of output cloud (Ex, En, He).

B. Implementation of Cloud Theory on Trust Evaluation

In this paper, the fuzzy-probabilistic model that cloud theory establishes, is utilized for trust evaluation of new registered UH Providers in UH environment. The proposed method adopts human knowledge regarding evaluation of healthcare providers' trustworthiness. Human thinking takes into consideration abilities, capabilities and other special attributes for determining the trustworthiness of an individual within a specific context [6]. In UH environment, UH Providers declares all information characterizing them into their User Profiles. The cloud-based method utilizes certain User Profiles attributes for predicting UH Providers' trustworthiness regarding UH service provision. The contribution of this paper is that proposes a generalized method for trust evaluation of new UH providers which utilizes specific User Profiles attributes depending on UH service. The notion of trust in UH environment is still considered to be trivial and therefore there is lack of established (User Profile) attributes that indicate trustworthiness of UH Providers (e.g. International Standards, National Legislation). On the other hand, in similar environments, such e-commerce, these attributes are well-defined, e.g. "quality of product", "price" etc [5]. For the implementation of the proposed trust evaluation method the case study of Psychiatric domain is considered. As addressed above, for the first-step implementation of this novel method, User Profile attributes have to be specified. For that purpose, a statistical investigation has been conducted with cooperation of Dromokaition Mental Hospital. It is the first attempt to define trustworthiness of psychiatrists given specific attributes. The collected data is analyzed from a MATLAB ANFIS and the following User Profile attributes are emerged:

- Number of examinations per week, on average, defined in the range [0, 50]
- Percentage of his/her patients that have been transferred to psychiatric clinic, defined in [0, 5%]
- Number of clinical studies that he/she has conducted in the last five years, defined in [0, 3]
- Availability, defined in [1, 9]

As in fuzzy set theory, each User Profile attribute constitutes a linguistic variable (e.g. availability) and its values can be mapped to linguistic terms (e.g. low, medium, high), as shown in Fig. 3. In other words, clouds define the mapping procedure of a value to a linguistic term. The depicted clouds are generated through CGs-1, in MATLAB software, given the data gathered from the aforementioned statistical investigation. The same approach was utilized for extraction of "TV" clouds, shown in Fig. 4.

The aforementioned User Profile attributes are correlated though qualitative inference rules (IF-THEN) for producing TV characterizing the UH Provider. These rules are determined through the MATLAB ANFIS applied to the

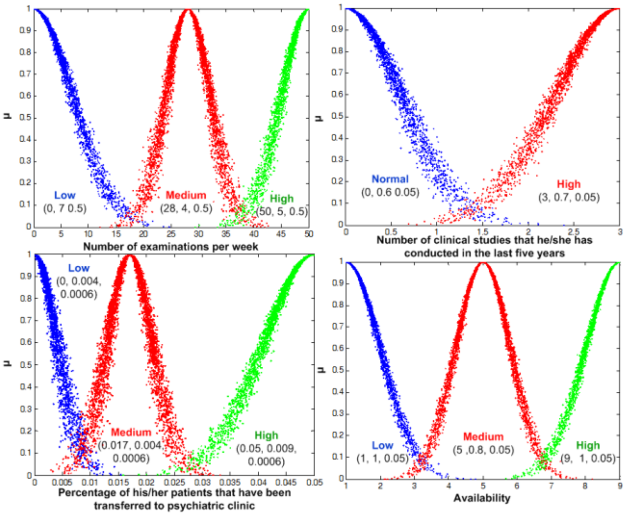

Figure 3. Input Clouds for User Profile attributes

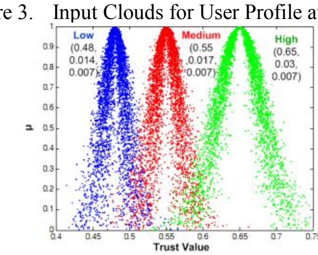

Figure 4. Output Clouds for Trust Value

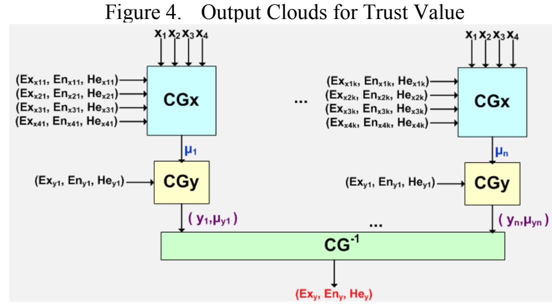

Figure 5. Cloud Inteference System

statistical data. As mentioned in the previous section, cloud theory defines that each qualitative inference rule is implemented by two cascading conventional and multidimensional CGs. Such an trust evaluation method is proposed to be implemented through a cloud inference system (CIS), via MATLAB software, as shown in Fig. 5.

The proposed CIS takes as inputs the crisp values of User Profile attributes as extracted from UH Provider's User Profile. As shown in Fig. 5 a number of conditional multi-dimensional cloud CGs determines the activation degree (μ_{xi}) for each antecedent ("IF" part of inference rule). Considering input (v1,v2,v3,v4,v5), CG_1 determines on what degree (μ_{x1}) the antecedent "IF x_1 is L AND x_2 is L AND x_3 is L AND x_4 is L " is activated, for the clouds define the corresponding linguistic terms (L, L, L). The different CGs, consisting this level of CIS, have the same inputs but different clouds. Given that this CIS is deployed on four linguistic variables analyzed into their corresponding clouds leading to $2*3^3$ CGs.

The second stage of CIS materializes the consequent part(THEN) of qualitative inference rule. Each cascading

CG takes as input the output of the first stage CG, given an output cloud for generating a cloud drop (y_i, μ_{yi}). As in fuzzy theory, conditional CG defines the value (y_i) of output, within a given output cloud, as well as the certainty degree (μ_{yi}) of that quantitative to qualitative mapping. For instance, the aforementioned attendance (IF) has activation degree μ_{x1} for the given inputs, the TV takes value y_1 with probability μ_{y1}, as the consequent part of rule defines (THEN TV is L). Rules determine the combination of input and output clouds.

Sequentially, the generated cloud drops from different CGs of second stage are geometrically accumulated from a one-dimensional CG^{-1} in order the final output cloud to be generated. In sense CG^{-1} produces a single cloud (Ex, En, He), where the representing value of cloud Ex is assigned to UH Provider's trust value. It is important to highlight that the output of a trust evaluation is consequent to be a cloud, since that procedure inherits fuzziness and randomness. However, the utilization of dominant value raises the robustness of trust evaluation method The utilization of cloud theory in combination with established attributes best captures the way UH Providers are evaluated in real-world by human beings.

IV. Evaluation

Two case studies are presented in this section for verify the feasibility and the effectiveness of this novel trust evaluation method. Considering two UH Providers that register in UH environment by creating their User Profiles. UH Provider-1 declares on his User Profile the following User Profile attributes (42,1,0.1%,5), while UH Provider-2 assigns to the corresponding User Profile fields the values (24,0,0.4%,7). For each case, the proposed method takes the declared values as inputs and generates a final cloud that is shown in Fig. 6. The TV of UH Provider-1 is determined as 0.67, because that value is the dominant in this final cloud. Similarly, to UH Provider-2 is assigned the TV 0.56. The flexibility of cloud-based method enables TVs to be in compliance to UH Providers' attributes, i.e. UH Provider-1 examines more patients, has conducted a clinic research and less of his patients have not appear health deterioration, in respect to the second. Furthermore, this novel method clearly offers the opportunity to UH Provider-1 to be selected for UH service provision, because of his high TV. On the contrary, the reported in literature TMSs would unfairly assign in both UH Providers the same TV equal to 0.5, irrespectively to their attributes. In that way, these TMSs rarely selects a new-registered UH Provider, in random, for UH service provision due to their low TVs.

V. Conclusion

In this paper a cloud-based Trust Evaluation method that utilizes User Profile attributes is introduced. Cloud theory is adopted because it mimics the human way of evaluation. This fact in combination with exploited User Profile attributes makes this novel method more flexible and fair.

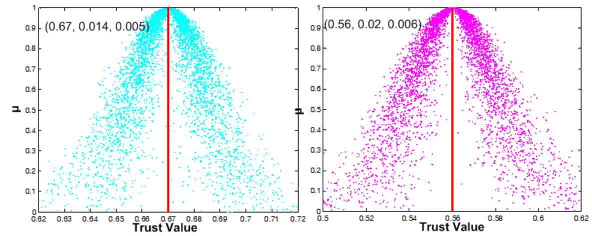

Figure 6. TV of UH Provider 1 and 2, respectively

References

[1] T.C. Panagiotakopoulos, D.P. Lyras, M. Livaditis, K.N. Sgarbas, G.C. Anastassopoulos, D.K.Lymberopoulos, "A Contextual Data Mining Approach Toward Assisting the Treatment of Anxiety Disorders," *IEEE Trans. on Information Technology in Biomedicine*, vol. 14, no. 3, pp. 567-581, May 2010.

[2] T. Panagiotakopoulos, P. Malliaris, M. Fengou, P. Gourzis, D. Lymberopoulos, , "Caregiving Social Networks. Are they adequate to support patients with anxiety disorders and how are they established?," *in Proc.* 10th IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB), Greece, 2010, pp.1-4.

[3] M.A. Fengou, G. Mantas, D. Lymberopoulos, "Group Profile Management in Ubiquitous Healthcare Environment," *in Proc*. IEEE Annual International Conference on Engineering in Medicine and Biology (EMBC), USA, 2012, pp. 2120-2123

[4] G. Athanasiou, G. Mantas, M.A. Fengou, D. Lymberopoulos, "Towards Personalization of Trust Management Service for Ubiquitous Healthcare Environment," *in Proc.* IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), to be published.

[5] Han Yu, Zhiqi Shen, C. Leung, Chuyan Miao, V.R. Lesser, "A Survey of Mutli-Agent Trust Management Systems," *IEEE Access*, 2013, vol.1, pp. 35-50.

[6] J. Matysiewicz, S. Smyczek, "Consumer Trust-Challenge for E-healthcare," *in Proc*. Fourth International Conference on Cooperation and Promotion of Information Resources in Science and Technology (COINFO), 2009, pp.333-338.

[7] W. Yan, D. Guan, S. Lee and Y-K Lee, "The role of Trust in Ubiquitous Healthcare environment," *in Proc*. 9th International Conference on e-Health Networking, Applications and Services, 2009, pp. 312-315.

[8] M. Blaze, J. Feigenbaum, and J. Lacy, "Decentralized Trust Management," *in Proc*. IEEE Symposium on Security and Privacy, Oakland, USA, 1996, pp. 164-173.

[9] W. Yuan, D. Guan and S. Lee, "Trust Management for Ubiquitous Healthcare," *in Proc*. International Symposium on Parallel and Distributed Processing with Applications, 2008, pp. 63-70.

[10] A. Boukerche, Ren Yonglin, "A secure mobile healthcare system using trust-based multicast scheme," *IEEE Journal on Selected Areas in Communications*, vol. 27, no. 4, pp. 387-399, May 2009.

[11] J. Valarmathi, V.R. Uthariaraj, G.A. Kumar, P. Subramanian and R. Karthick, "A novel Trust Management Scheme in Pervasive Healthcare," *in Proc*. 2nd International Conference on Information Management and Engineering (ICIME), 2009, pp.141- 145.

[12] M. K. Denko, I. Woungang, M.S. Obaidat, "Trust Management in Opportunistic Pervasive Healthcare Systems," *in Proc*. IEEE 16th International Conference on Electronics, Circuits and Systems, (ICECS), 2009, pp. 832-835.

[13] G. Athanasiou, G. Mantas, M.A. Fengou, D. Lymberopoulos, "A profile-based Trust Management Scheme for Ubiquitous Healthcare Environment," *in Proc.* 13th IEEE International Conference on Bioinformatics and Bioengineering (BIBE), Greece, 2013, pp.1-5.

[14] Li De-yi, Shi Xue-mei, P. Ward, "Membership cloud and membership cloud generator," *Journal of Computer Research and Development*, vol. 32, no. 6, pp. 15-20.

[15] Li De-yi, Shi Xue mei, P. Ward, et al. "Soft inference mechanism based on cloud models," *in Proc*. 1st International Workshop on Logic Programming and Soft Computing, Bonn, Germany, 1996.