Available online at 2019.creative-construction-conference.com/proceedings/

CCC 2019

Proceedings of the Creative Construction Conference (2019) 124

Edited by: Miroslaw J. Skibniewski & Miklos Hajdu

https://doi.org/10.3311/CCC2019-124

Creative Construction Conference 2019, CCC 2019, 29 June - 2 July 2019, Budapest, Hungary

Simulating interaction dynamics of refurbishment project stakeholders through agent-based modeling towards enhancing BIM adoption effectiveness

Anthony Okakpu[a,] *, Ali GhaffarianHoseini[a], John Tookey[a], Jarrod Haar[b], Amirhosein Ghaffarianhoseini[a], Tongrui Zhan[a], Okechukwu Nwadigb[a]

[a]*Department of Built Environment Engineering, School of Engineering, Computer and Mathematical Sciences, Auckland University of Technology, New Zealand*

[b]*Department of management, Faculty of Business management, Auckland University of Technology, New Zealand*

Abstract

Building Information Modelling (BIM) is an IT enabled technology that supports information sharing, access, update of data and use, and allows storage of information and management. While the technology itself is not new, similar approaches have been in use for the construction of new builds, but the refurbishment domain is yet to catch up with the ability to exploit BIM benefits. The study offers an avenue to investigate the effectiveness of adopting BIM for complex refurbishment projects through a simulation of the interaction of refurbishment project stakeholders network using agent-based modelling performed through a parameterized Bayesian network. Previous investigations show that stakeholders hold the common ground to make effective decision towards adoption of BIM for complex refurbishment project. The aim of this paper is to present the results of current simulations made using Hepar II network on the interaction of project stakeholders for refurbishment project case study of a tertiary institution in New Zealand. In addition, the paper investigates whether there are benefits towards adoption of BIM considering the influences of the modification of the threshold error parameter on the final factor observation states.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2019.

Keywords: Building Information Modelling (BIM); Refurbishment project stakeholders; Interaction Networks; agent-based simulation

1. Introduction

BIM is a construction management tool for managing engineering problems that involves design, energy efficiency analysis, maintenance, documentation, and delivery for all different phases of project life cycle [1]. A strategic approach to BIM adoption requires the incorporation of people, process, and technologies on timely bases, it also leads to capacity buildings and good managerial improvements [2]. Recently, BIM has captured the attention of the construction sector due to its widely recognized benefits for building projects [3, 4], yet the use of BIM for refurbishment projects is just emerging [5]. Based on the existing literatures, while [6] advocates that to maximise BIM adoption for complex refurbishment projects, there is a need to examine whether there is real BIM benefits through a healthy interaction of refurbishment project stakeholders, following that the stakeholders are the actors who influence the operation of various economic actors in various ways [7]. Although, social interaction fosters the emergence groups with a common interest of different stakeholders to a shared solution. Hence, the decision to

*Corresponding author: Anthony .I. Okakpu email: ifectony@yahoo.com

innovation becomes a bidirectional communication process which requires specific programs and skills and at the same time coordinate many players, variables, problem solving and conflicting interests. Therefore, the use of decision support systems such as Bayesian models based on quantitative methods can investigate healthy interactions in projects [8] in other to identify BIM effectiveness. Therefore, the main objective of this study is to compare traditional refurbishment project network and BIM prototype network by simulation of uncertainties (error conflict) through the network of project stakeholders. In other to achieve the objective, this study is structured into three parts. The first part is the literature review which discusses about stakeholders and the use of agent-based modelling, the second part discusses about the methodology while the third part presents the result and the analysis, then followed by the conclusion.

2. Literature review

The aim of literature review is to introduce the importance of stakeholders and as well as the agent-based modelling in construction projects. These factors have been used in this study to investigate the effectiveness of BIM for refurbishment project based on project network interactions.

2.1. Stakeholder theory and engagement

The concept of "stakeholder" has been said to be derived from Economy, indicating that the power of organisations depends on the relationship of its stakeholders [9]. [10] has documented a chronology of the concept of stakeholders and their key constructs in theory and their identification in construction projects. The refurbishment stakeholders are those actors that have an interest in a particular refurbishment project [11]. Accordingly, one characteristic of the AEC industry is the unconventional nature of networks of stakeholder interaction which constitute building and construction projects [12]. This has contributed to the challenges within projects including knowledge transfer in organisations and the diffusion of innovation propensity [13]. Since the complexities in refurbishment project requires specific tools, an investigation of project interaction by comparing traditional method vs BIM method would help to identify the knowledge of information exchange among different and encompassing stakeholders involved in refurbishment project BIM adoption decision. Therefore, the current study investigates within stakeholders interaction because through this means, a real-world problem will be solved [14].

2.2. Agent-based model of stakeholders' interaction

Agent based modelling (ABM) is a computer simulation for analysing complex interaction between multiple agents. In other worlds, the simulation is carried out on "the observed world called actors (agents) with certain behaviour which is dependent on the state of the environment" Each of the agents can act locally in response to a stimuli when they communicate with other agents [15]. ABM dynamics models have been widely used to investigate social interaction in stakeholder networks and these would be typically reproduced at the participatory decision-making processes in construction projects [16]. For example, the social network analysis has been used to simulate interaction of project stakeholders [17], but lacks the capacity to determine the level of performance of networks between traditional projects and BIM projects, and to identify which network favours identification of project uncertainties. To correct the deficiency in social network analysis (SNA), there are other set up such as "Virus in a network" using Netlogo software [18]. This method of simulation has benefits but also limited to assessing the general capacity of the network but cannot determine the individual stakeholders' contribution or sensitivity within the project network. Therefore, the current study covers this gap by adopting Bayesian network using Hepar II model to simulate the refurbishment project network for investigation of real-time benefits between the two project networks.

3. Methods

An agent-based Bayesian network has been built to model and simulate the interaction of project stakeholders for a recent completed refurbishment project is presented. The project stakeholders are represented by the nodes of a network

linked to each other based on their social interaction. A questionnaire designed to obtain the interaction network is administered on the project stakeholders who participated on a recent refurbishment project in a tertiary institution in Auckland. Owing to the shortage and lack of interest of refurbishment stakeholders on BIM interest, a snowball technique was used to identify and nominate the participants who were involved in the project to enable modelling of the interaction network to locate the potential interviewees. Before conducting the quantitative interview, approval was sought from the [19]. This was to protect the safety, privacy, health, welfare and social sensitivities of the various participants involved in the provision of research data. Table 1 details the demographic representation of the research participants

Table 1: over view of the participant demographic information

CODE	Categories of participants	No of experts	Years of experience
PM1, PM2	Project Managers	2	5 – 12
MC	Main Contractor	2	8 – 15
SB1, SB2	Sub-contractors	2	10 – 16
M1, M2, M2	BIM Managers	4	4 – 8
C1, C2	Consultants	2	10 – 22
AR1, AR2	Architects	2	8 – 15
CR	Client representative	1	8 – 12
SU	Space Users	3	6 – 10
Total		18	

The demographics of the participants reveal different levels of experience, and the categories of participants majorly from client organisation (tertiary institution). This could enhance the transferability of the results to readers for their applications, and this can promote the validity and reliability of findings [20].

The nature of the interview was a collaboration questionnaire designed to extract the intensity of interaction among the project stakeholders. For example, the project stakeholders can be asked to list the number of stakeholders they interacted during the project and how often they interacted. The rate of interaction can be measured with “frequent” “less frequent” and “none”

4. Results and Discussion

We adapted Hepar II network using Bayesian network model. The Bayesian network models are acyclic directed graphs modelling probabilistic dependencies and independencies among variables. In this study, the dependencies and independencies occur between nodes or also called the project stakeholders. The graphical part of Bayesian network shows the structure of interaction among the project stakeholders and this are quantified by conditional probability distributions [21]. In order to adapt Hepar II network, we considered the effects of the level of complexities of the networks but less consideration to the level of initial error break-out. The disorders are considered as the error introduced into the network and are allowed to simulate through the network as “designed error” The time to identify the error, error percentage, recovery chance is measured by each node in the network. The nodes are set as observers with a defined probability of occurrence of 0.3 %, 0.3 % and 0.4 % respectively. Table 2 shows the parameters for the Bayesian network model.

Table 2: the parametric used by GeNIe

Parameter	**Definition**	**Applied values**
Target node	Number of individuals generating design error	Percentage of individuals
Observation node	Frequency of design error checks to identify errors	Number of weeks
Time	Time to identify error	Final percentage
Error percent	The quantity of error perceived by each node	Number of percentage increase
Recovery chance	Probability of an individual not continue to do error	Number of percentage decrease

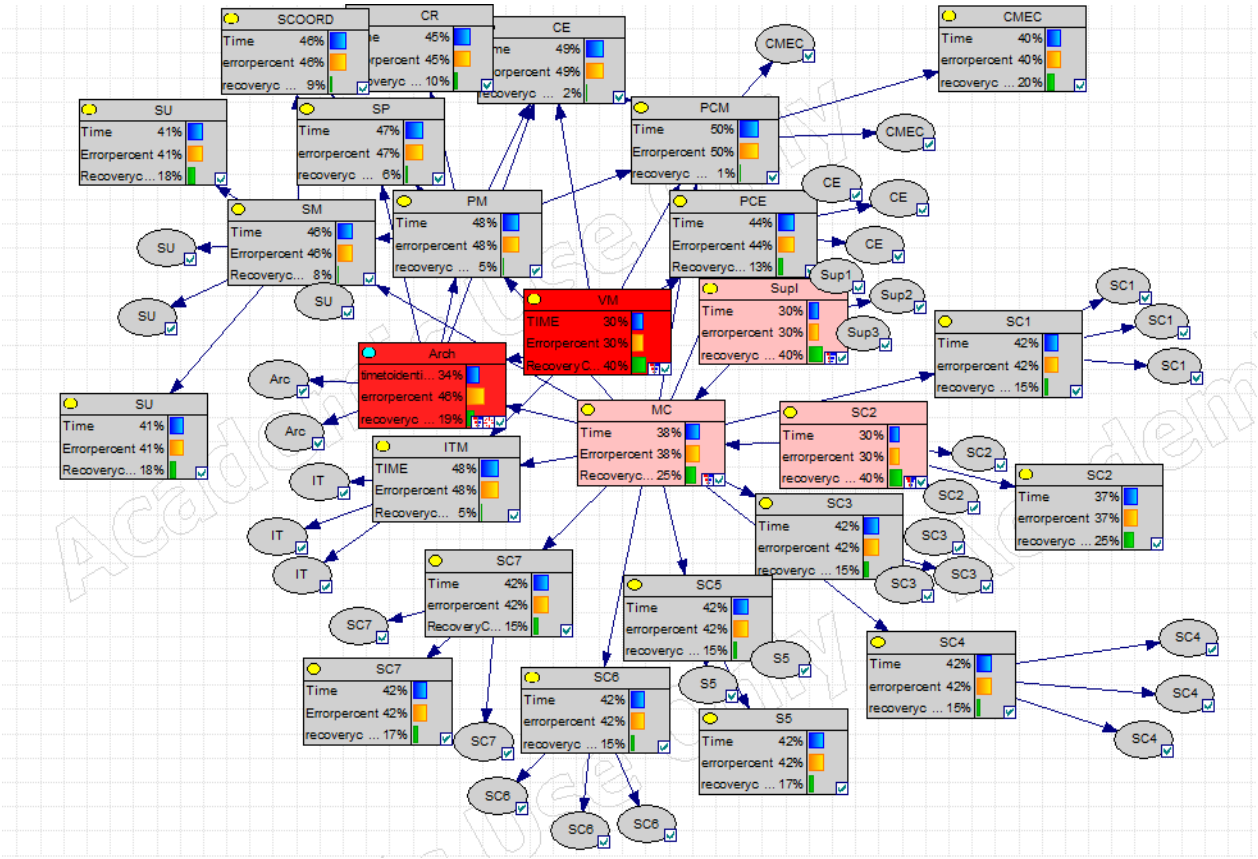

Figure 1: The traditional project network A

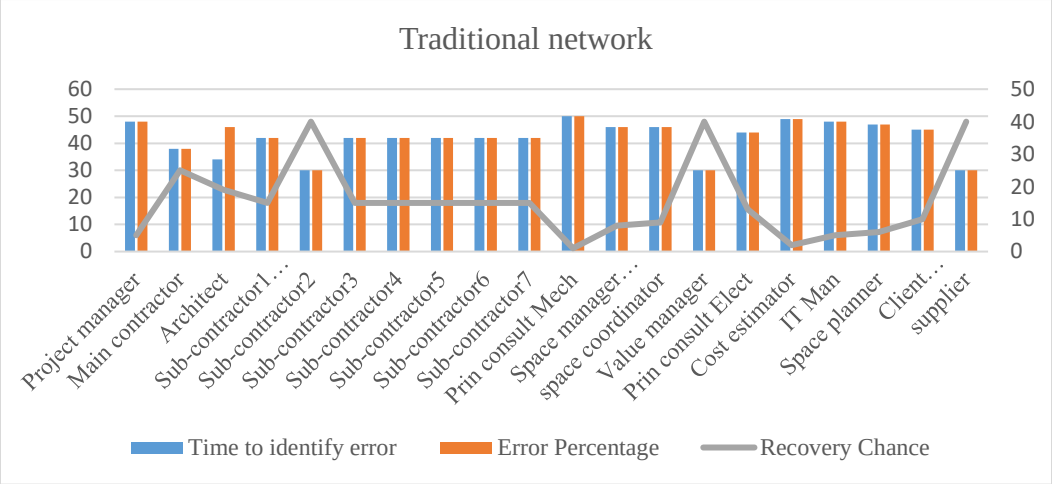

Figure 2: Simulation result for the main traditional network

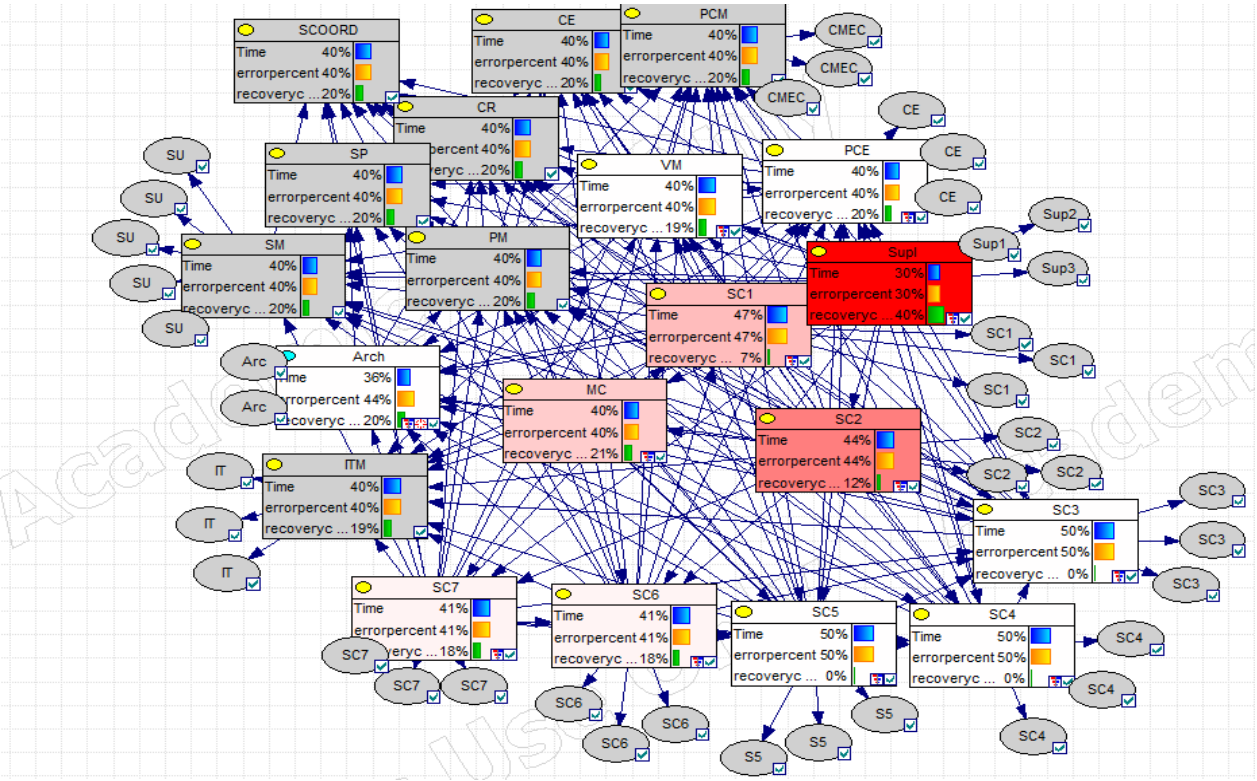

Figure 3: The virtual BIM project network

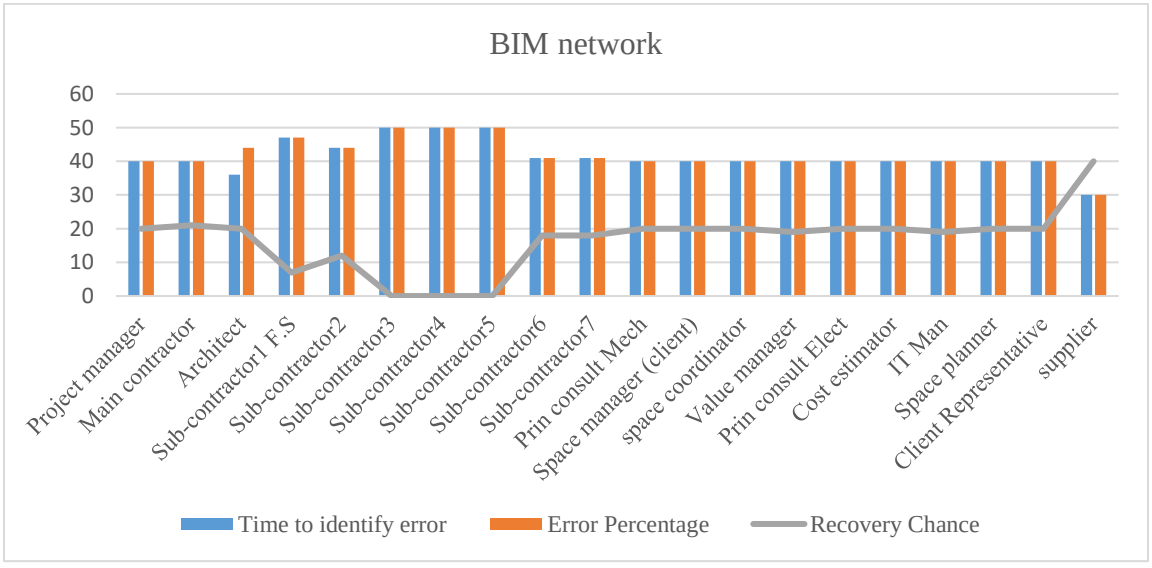

Figure 4: simulation result for error propagation on BIM network

5. Conclusion

This paper examined the relationship between the traditional refurbishment project network and a BIM prototype network in the same environment using Bayesian network model to investigate if BIM would be effective and beneficial for stakeholders who refurbish existing buildings in a tertiary institution setting. The result indicate that the

Bayesian network was very effective in identifying the impact of the different stakeholders in the project network. The error introduced at the architect domain has different impacts on the two project networks. Although the two networks show the same pattern of error propagation, there are differences based on the impact of errors on the project stakeholders. The agent-based model indicates in each network (Figures 1&3) the project stakeholders who are likely to be highly influenced by the introduction of error by different their colours on the nodes. The red coloured box/es indicates that the stakeholders are negatively impacted while the white colouration shows positive impact. This is also evident based on the simulation result of the error propagation observation of each node as shown in Figures 2&4). The plots represent the overall diffusion of errors, recovery time, and the percentage of error perceived.

In summary, the result shows that it takes more time for traditional project network to recover from uncertainties such as design error compare to BIM network. It also indicates that stakeholders in a BIM network almost identify errors and recovers at the same momentum compared to the traditional network. The main architect who makes the error recovers instantly at the BIM network compare to the traditional network. This is because of the improved linkages (or edges) offered by the BIM network creating a stronger social network with increased collaboration between the project team members. Overall, the simulation result is a justification for BIM adoption for refurbishment projects regardless of the size of the project. Future work might examine the identification of real benefits of BIM on the refurbishment project using sensitivity analysis. Another option might be a desktop audit, which might be suitable to validate the different networks as shown in the study.

References

1. Venkrbec, V., M. Galić, and U. Klanšek, *Construction process optimisation–review of methods, tools and applications.* Građevinar, 2018. **70**(07.): p. 593-606. https://doi.org/10.14256/JCE.1719.2016
2. Alwan, Z., *BIM performance framework for the maintenance and refurbishment of housing stock.* Structural Survey, 2016. **34**(3): p. 242-255. https://doi.org/10.1108/SS-03-2015-0018
3. Eastman, C., et al., *A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators*. 2008, John Wiley and Sons, Hoboken, NJ.
4. Bryde, D., M. Broquetas, and J.M. Volm, *The project benefits of building information modelling (BIM).* International journal of project management, 2013. **31**(7): p. 971-980. https://doi.org/10.1016/j.ijproman.2012.12.001
5. Ghaffarianhoseini, A., et al., *Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges.* Renewable and Sustainable Energy Reviews, 2016. https://doi.org/10.1016/j.rser.2016.11.083
6. Okakpu, A., et al., *A proposed framework to investigate effective BIM adoption for refurbishment of building projects.* Architectural Science Review, 2018: p. 1-13. https://doi.org/10.1080/00038628.2018.1522585
7. Menassa, C.C. and B. Baer, *A framework to assess the role of stakeholders in sustainable building retrofit decisions.* Sustainable Cities and Society, 2014. **10**: p. 207-221. https://doi.org/10.1016/j.scs.2013.09.002
8. Cascetta, E., *Transportation systems analysis: models and applications*. Vol. 29. 2009: Springer Science & Business Media.https://doi.org/10.1007/978-0-387-75857-2
9. Freeman, R.E., *Strategic management: A stakeholder approach*. 2010: Cambridge university press. https://doi.org/10.1017/CBO9781139192675
10. Mitchell, R.K., B.R. Agle, and D.J. Wood, *Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts.* Academy of management review, 1997. **22**(4): p. 853-886.https://doi.org10.2307/259247
11. Beringer, C., D. Jonas, and A. Kock, *Behavior of internal stakeholders in project portfolio management and its impact on success.* International Journal of Project Management, 2013. **31**(6): p. 830-846. https://doi.org/10.1016/j.ijproman.2012.11.006

12. Linderoth, H.C., *Understanding adoption and use of BIM as the creation of actor networks.* Automation in construction, 2010. **19**(1): p. 66-72. https://doi.org/10.1016/j.autcon.2009.09.003

13. Linderoth, H.C. and M. Jacobsson. *Understanding adoption and use of ICT in construction projects through the lens of context, actors and technology*. in *Proceeding of CIB W*. 2008.

14. Freeman, R.E. and J. McVea, eds. *A stakeholder approach to strategic management*. The Blackwell handbook of strategic management. 2001. 189-207. https://dx.doi.org/10.2139/ssrn.263511

15. Voinov, A. and F. Bousquet, *Modelling with stakeholders.* Environmental Modelling & Software, 2010. **25**(11): p. 1268-1281. https://doi.org/10.1016/j.envsoft.2010.03.007

16. Park, H., et al., *Social network analysis of collaborative ventures for overseas construction projects.* Journal of construction engineering and management, 2010. **137**(5): p. 344-355. http://dx.doi.org/10.1061/(ASCE)CO.1943-7862.0000301

17. Alarcón, D.M., I.M. Alarcón, and L.F. Alarcón. *Social network analysis: A diagnostic tool for information flow in the AEC industry*. in *Proceedings for the 21st Annual Conference of the International Group for Lean Construction*. 2013.

18. Le Pira, M., et al., *Finding shared decisions in stakeholder networks: an agent-based approach.* Physica A: Statistical Mechanics and its Applications, 2017. **466**: p. 277-287 https://doi.org/10.1016/j.physa.2016.09.015.

19. Auckland University of Technology ethics. *Applying for ethics Approval: Guidelines and Procedures*. 2018 [cited 2018 June 15, 2018]; Available from: https://www.aut.ac.nz/research/researchethics/guidelines-and-procedures.

20. Merriam, S.B. and E.J. Tisdell, *Qualitative research: A guide to design and implementation*. 2015: John Wiley & Sons. https://doi.org/10.1177%2F0741713616671930

21. Seixas, F.L., et al., *A Bayesian network decision model for supporting the diagnosis of dementia, Alzheimer′ s disease and mild cognitive impairment.* Computers in biology and medicine, 2014. **51**: p. 140-158. https://doi.org/10.1016/j.compbiomed.2014.04.010