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A Complex Systems Framework Approach Towards Multidisciplinary Tumor Boards

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***Abstract*— Multidisciplinary tumor boards (MTBs) are universally recommended and have been used in treatment of late stage cancers. Tumor boards have the advantage of including all the stakeholders in the decision making process and improving quality of care, however several studies have pointed to their lack of efficiency and tend to be lackluster while not producing the desired benefits for the participants. In this paper we present the design of a web based immersive framework for collaborative decision making that has the potential to improve several inefficiencies in conducting tumor boards and improve overall clinical outcomes. We present the design of our framework and use late stage cancer treatment as an example to explain its software components and its role in improving communication, treatment time and the overall decision making process. The framework which has been successfully used in other collaborative decision-making environments has the potential to transform how tumor boards could dramatically improve the quality of cancer care in the future.**

I. Introduction

Recently there has been a rise in the implementation of multidisciplinary tumor boards at several medical and clinical facilities and institutions. There have been reported improvements by using MTBs for colorectal cancer treatment [1]. This multidisciplinary setting comprises of surgeons, clinical and medical oncologists, radiologists, pathologists and coordinators. The two important factors that determine the smooth function of tumor boards are 1) the availability of information from all disciplines and 2) the ability of the participants to communicate effectively [2]. Until recently there was no availability of metrics to assess the quality of the MTBs to maintain standards of information and communication. In [3] a "Colorectal Multidisciplinary Team Metric for Observation of Decision-Making (cMDT-MODe)" is presented as a validated tool for quality assessment of MDTs. This method requires a rigorous audit form to be used during the MDTs as an observational tool for populating several performance scores. In this paper we propose a novel solution for conducting MTBs that is fully immersive and participants join via a web-based virtual platform. The platform can improve information flow, deliver effective communication between the participants and automatically provide built-in standards and metrics for quality assurance. The platform has been under development for over a decade and has been used successfully in other decision-making environments. The main contribution of this paper is to introduce to the clinical community the design considerations for developing this platform, describing the necessary software components that drive the decision making process and connecting how the platform architecture and the software components can be tailored for the purposes of conducting MTBs.

II. BACKGROUND

MTBs have evolved over the past decade from being irregular meetings held at the discretion of the physician and not guaranteed to discuss all the cancer cases and only those that are special. Recently they have become more structured and mandatory in nature where all cases area at least briefly discussed by all the constituents attending in a formal setting and the more special cases are discussed at length. There have been some instances where MTBs are conducted with participants joining via video-conferencing. However, it is to be noted that all MTBs are conducted in a physical setting with participants joining at a particular scheduled time either physically or virtually. Recently due to the increase in subspecialized cancer treatments MTBs have become organ-specific and in a clinical cancer treatment setting there could be several MTBs that meet based on the effected organ.

A. Decision Making Software Systems

Multi-criteria decision making (MCDM) [4] has become popular model for decision making in several application areas ranging from water planning systems to energy management [5, 6]. MCDM is a class of decision making which deals with decision problems when there are several decision making criteria. Further distinction is made based on the number of decision making entities into single or group decision making methods. In the group based model, a number of alternatives are evaluated against a set of attributes and the best alternative is selected by comparing against each attribute. Most group based decision making software systems [7] follow this model for decision making. The software primarily addresses the following features: 1) choose decision options 2) choose evaluation criteria 3) obtain performance measures 4) transform all measures into a unified system or scale 5) assign weights to reach evaluation criteria 6) rank and score the options 7) make a decision.

B. Group Decision Making Systems in Healthcare

Healthcare settings have started to adopt the MCDM model for collaborative decision making. A systematic review of MCDM methods in healthcare is provided in [8]. It reports that further research is needed for practice of MCDM in group based decision making setting in healthcare. In [9] a MCDM model was used to evaluate several electronic medical records

(EMR) packages. In [10] a study was conducted using Annalisa, a MCDM based decision making tool, that revealed that better decisions were made by participating clinicians as the MCDM model helped promote shared decision making and transparency. While there have been some studies done on the acceptability of MCDM methods in healthcare, there still is a real need for its adoption in practical settings. MTBs seem to be a natural fit for adopting the MCDM model of decision making.

III. Complex Systems Framework

Based on MCDM, a flexible decision-support system to integrate a range of computational models for complex systems within a common cyber-framework specifically designed for use in a decision-making context has been developed. This Complex System Framework (CSF) provides a high-level environment that can link together different sophisticated computational models so that the output of one sub-model or process can provide input to another one. This allows workflows that automatically process and aggregate numerical and graphical output to be defined. It also enables the creation of graphical dashboards that are linked to models to permit interactive input and output in multi-screen environments as well as groups of desktops, laptops, tablets, or even smartphones. The CSF allows for the creation of decision environments and includes visualization, decision making and engagement sessions. Through CSF‟s web-based open source platform, models can be securely displayed and utilized in decision centers and on laptops, tablets, and smartphones - globally via web connections. This flexibility allows for significant expansion opportunities thus increasing and broadening impact and availability.

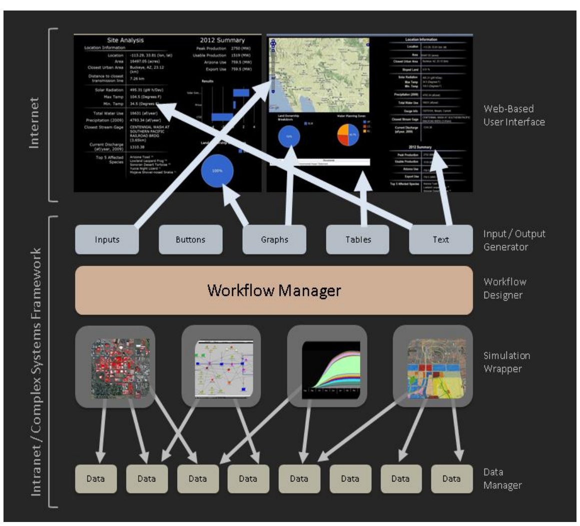

Figure 1. The software architecture of the Complex Systems Framework

As shown in Figure 1, the framework is built using open source software. The main data storage is a Postgres/ PostGIS database which handles tabular data including, in part, vector data, metadata and administrative data needed to coordinate the clients of the system. The interface generator and the workflow manger are written in a combination of PHP scripting, Javascript and HTML. A load balanced high availability Apache webcluster is utilized for internet distribution, so that every HTML 5 capable browser is able to access and interact with Decision Tools that are generated with the CSF. The wrapping of simulations happens in PHP-scripting, which can be directly edited within an online interface. Each model is wrapped in a module that can then be used (and reused). In this process the inputs and the outputs of each model are specified and the model is stored in an immediately executable form such that the framework can access it. Models that use graphical user interfaces are stored and executed on a set of virtual machines that exclusively run one model in a clean environment.

A. *Application of CSF in Other Decision Making Settings*

In this example, policy makers must be able to analyze and determine the best possible means to provide power to the state of Arizona. Furthermore, participants must be able to make informed decisions based on the power benefit versus the economic and environmental cost of any type of power installation, including coal-fired or solar-panel plants. The decision environment must also take into account how current power lines and line capacities influence power distribution.

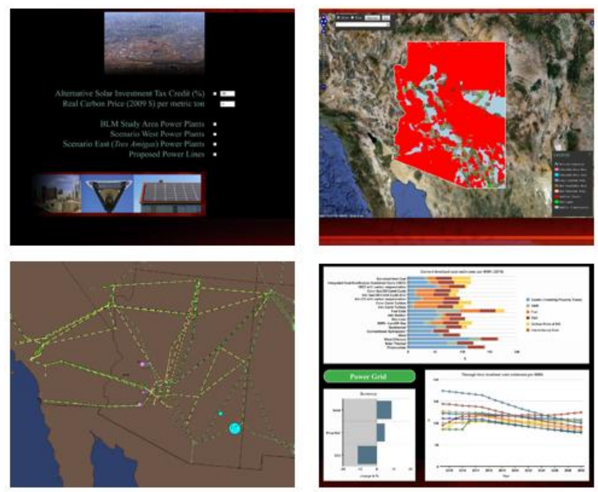

Figure 2. Application of CSF for energy planning

Figure 2, shows the decision making steps followed during this application: 1) make policy changes 2) visualize the geo-spatial impact 3) visualize the power grid 4) analyze the impact of the decision on the components of the grid over a futuristic timeline. The policy makers were constituents from a multi-disciplinary setting; they included legal experts, zoning experts and environment and sustainability scientists. The attributes that drive the decision making have different meaning to each of these constituents, the application takes into consideration a weighted sum of the impacts across the different domains and the input data is processed across several validated models that are specific to each domain. For example, the attribute data in this example is processed by the MCDM BOCR-ANP model [11] for renewable energy consumption and an ANP-DEMATEL [12] for land use and zoning.

CSF provides the computational structure for an enterprise ready decision environment that consists of seven screens. The multi-level system allows users to input key variables such as power station location and type. It also allows users to analyze the impact of power generation. The environment generates a cost-benefit analysis of financial cost and environmental impact for each potential power station. Once a user has selected a location and type for a new power generating station, the system automatically maps, calculates, and displays the expected costs, environmental impact, amount of new power generated, and the locations that new power will be able to reach. This allows the decision-maker to view the overall impact of potential power generating stations, easily compare and contrast options, and finalize decisions in a completely informed manner.

CSF has been successfully implemented in several other application areas that include 1) developing a decision support system for Arizona farmers and water resource managers by integrating evapotranspiration data with local water costs 2) creating an enhanced decision support system for criminal justice interventions by combining statistical and geographical data & 3) developing a budget analysis tool that enables law makers, economists and the layman to better understand the implications of the State of Arizona's budgetary changes.

IV. Platform Design for MTB

CSF can easily be adopted to reform the medical approach to the diagnosis and treatment of cancer with MTBs. While current MTBs are able to relay static data from medical charts, they lack interactivity between patients, their doctors, different specialists, patient advocates, and all other stakeholders. The proposed platform will aid the treatment decisions made by MTBs, by providing interactive features, visual displays, and a database of treatment options and is used to visualize the interdependence of a patient's many treatment components in real-time. This multi-level system will allow doctors to input patient data, diagnostic images and information through tablet applications, as well as import medical history and EMR data. This information feeds into the platform and is displayed via a multi-screened decision environment for use in the tumor board setting. Patient information will automatically generate a selection of customized treatment options for that patient, as well as information on the success and side effects of those treatments, allowing doctors to make better decisions about patient care.

Features of the platform include visual display and background information on the genetic profile of the patient, radiology and pathology reports, and dynamic timeline visualizations of patient health and treatment success. Multiple monitors are used to display these features and generate intuitive, effective visual aids, allowing doctors and other medical professionals to collaboratively work to improve patient care.

A. *Software Architecture*

As shown in Figure 3, the procedure for making clinical decisions for late stage breast cancer can be quite complex. The platform developed takes into account datasets originating from screening, diagnosis, patient background, patient quality of life, medical history, timeline, genetic information and current and future treatment options. Several clinicians and medical professionals interact with the auto-generated dashboards that are a result of processing these datasets. These dashboards contain several different treatment options for all the participating medical professionals and are presented as recommendations. Each participant has the ability to view all the other participant's recommendations and independently vote for the desirable outcome. All outcomes are then scored and the highest combined score is chosen as the optimal outcome. The next section shows the major interaction screens provided by the platform to promote proper information flow as well as collaborative decision making.

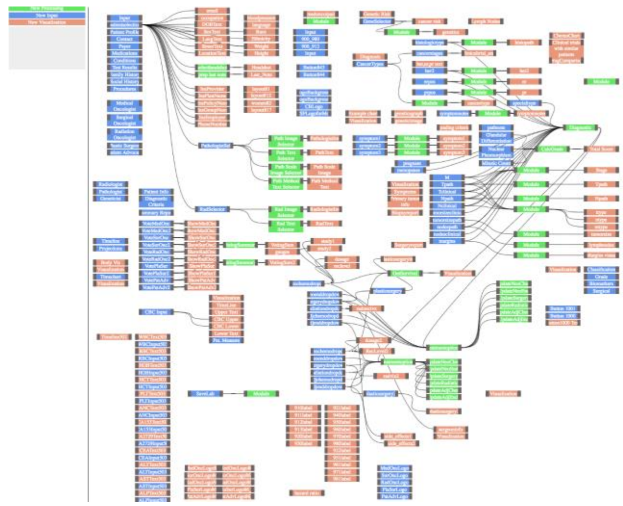

Figure 3. The procedure flowchart for breast cancer

B. *Interaction Screens*

The interaction populated by the platform are broadly classified into two sets aimed at improving the two most important factors while conducting MTBs information and communication. The screens are based on choosing breast cancer as an example domain. Figure 4 shows the interaction screens for sharing patient information available to all the participants while collaboratively working on a patient's case. 1) the clinical exam and diagnosis results 2) the treatment options 3) the timeline of medical records or historical data 4) data from genetic testing.

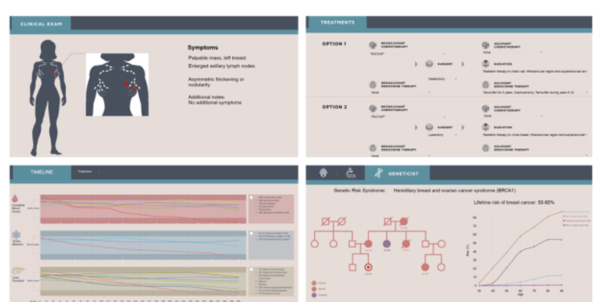

Figure 4. Interaction screens related to patient information

Figure 5 shows the interaction screens for communication and decision making that are available to the participants to help arrive at quality decisions rapidly. These include the notes and suggestions made by the several clinicians (clinical oncologist, surgical oncologist, pathologist etc.) and also advocacy group and clinical coordinators. Finally every participant is able to vote on the available options and a final score is populated by the platform to decide on the treatment.

Figure 5. Interaction screens related to communication and decision making

C. *Quality Assurance*

One of the major advantages that CSF offers while conducting MTBs is the ability to track and monitor all interaction data. This helps improve accountability and confidence in the participants during the decision making process. This also reduced the need to have an observational tool discussed in [3] to perform quality assurance by populating rigorous audit forms and scoring on chosen metrics. The whole process of quality assurance and evaluation of MTBs can easily be automated inside the platform. The process of clickstream analysis [13] works extremely well in this situation. It has also been used other mobile applications [15] to measure user participation, satisfaction and acceptance. Click-streaming is a process of interaction analysis where software design is compared with its usage/usability metrics. Over a process of continuous improvement and refinement the click-streaming data reaches a point where no further improvements are necessary. Once this optimal condition is reached then the same data is used for the purposes of measuring quality assurance. In brief the method observes sequence of interactions (click-streams) by the participant to understand the completion of the tasks and compares that to the intended tasks. Over time the actual and intended tasks converge and the application is now ready to perform quality assurance. Since all the interactions by participants happen via the web-based interface, the platform can easily perform click-streaming and remove the necessity to have other ways to track performance.

V. Conclusion

In this paper we have presented the software design and architecture for a virtual, immersive and collaborative decision making platform that can be used to replace MTBs. The platform addressed the two most prevalent factors that make current MTBs inefficient; information sharing and effective communication. It also presents additional benefits of easily integrating automated evaluation and maintain standards while conducting these MTBs by using click-streaming techniques. In the future we plan to work with medical facilities and clinics to validate the platform and compare its performance as a novel method to conduct MTBs.

While CSF has been successfully shown to be a useful tool to help make decisions among an inter-disciplinary set of stakeholders, it has not been thoroughly tested for use in the medical setting. Tumor boards offer an excellent opportunity to build upon the expertise gained via the projects mentioned in the paper. The ~~first~~next step in the process ~~would be to develop verification approaches to prune and validate the model.~~is to build and test a model with medical practitioners to validate the efficacy of our approach. ~~Further steps would be to identify and include various medical practitioners from the various disciplines involved in a tumor board.~~ Upon successful validation, we intend to build additional CSF models across the medical spectrum.

Acknowledgment

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References

[1] Fallowfield, L. (2014). Tumor boards: optimizing the structure and improving efficiency of multidisciplinary management of patients with cancer worldwide. American Society of Clinical Oncology.

[2] Seretis, C., Mankotia, R., Goonetilleke, K., & Rawstorne, E. (2014). Quality assessment of decision–making in colorectal cancer multidisciplinary meetings. *Journal of BU ON.: official journal of the Balkan Union of Oncology*, 19(4), 913.

[3] Shah, S., Arora, S., Atkin, G., Glynne-Jones, R., Mathur, P., Darzi, A., & Sevdalis, N. (2014). Decision-making in Colorectal Cancer Tumor Board meetings: Results of a prospective observational assessment. *Surgical endoscopy*, 28(10), 2783-2788.

[4] Greco, S., Figueira, J., & Ehrgott, M. (2005). *Multiple criteria decision analysis*. Springer's International series.

[5] Pohekar, S. D., & Ramachandran, M. (2004). Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and sustainable energy reviews*, 8(4), 365-381.

[6] Hajkowicz, S., & Collins, K. (2007). A review of multiple criteria analysis for water resource planning and management. *Water resources management*, 21(9), 1553-1566.

[7] Mosavi, A. (2013). A MCDM software tool for automating the optimal design environments, with an application in shape optimization. In Proceedings of *International Conference on Optimization and Analysis of Structures*.

[8] Adunlin, G., Diaby, V., & Xiao, H. (2015). Application of multicriteria decision analysis in health care: a systematic review and bibliometric analysis. *Health Expectations*, 18(6), 1894-1905.

[9] Zaidan, A. A., Zaidan, B. B., Al-Haiqi, A., Kiah, M. L. M., Hussain, M., & Abdulnabi, M. (2015). Evaluation and selection of open-source EMR software packages based on integrated AHP and TOPSIS. *Journal of biomedical informatics*, 53, 390-404.

[10] Dowie, J., Kjer Kaltoft, M., Salkeld, G., & Cunich, M. (2015). Towards generic online multicriteria decision support in patient-centred health care. *Health Expectations*, 18(5), 689-702.

[11] Kabak, M., & Dağdeviren, M. (2014). Prioritization of renewable energy sources for Turkey by using a hybrid MCDM methodology. *Energy Conversion and Management*, 79, 25-33.

[12] Azizi, A., Malekmohammadi, B., Jafari, H. R., Nasiri, H., & Parsa, V. A. (2014). Land suitability assessment for wind power plant site selection using ANP-DEMATEL in a GIS environment: case study of Ardabil province, Iran. *Environmental monitoring and assessment*, 186(10), 6695-6709.

[13] Lettner, F., Grossauer, C., & Holzmann, C. (2014, September). Mobile interaction analysis: towards a novel concept for interaction sequence mining. In Proceedings of the *16th international conference on Human-computer interaction with mobile devices & services* (pp. 359-368). ACM.

[14] Patwardhan, M., Stoll, R., Hamel, D. B., Amresh, A., Gary, K. A., & Pina, A. (2015, October). Designing a mobile application to support the indicated prevention and early intervention of childhood anxiety. In Proceedings of *the conference on Wireless Health* (p. 8). ACM.