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Using Architecture Models to Design Adaptive Socio-technical Systems

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Abstract

An architecture framework is used to capture the overall design and structure of a complex system. The Human Viewpoint was developed to augment existing architectural frameworks with additional information relevant to the human component in the system. The Human View models collect and organize social parameters in order to understand the way that humans interact with other elements of the system; the Human View models define the socio-technological boundaries of the system. Analyses performed with the architectural data provide information regarding the congruence, or fit of the human and the system. For example, different key thread analyses identify problematic paths involving human level activities and their intersection with technology. Additionally, node analyses are performed to ensure the flexibility of the human system by evaluating the alignment of roles, tasks, and the impact of constraints. This results in a transition graph for the human system providing paths for adaptation, i.e., the lattice can be used to re-align roles and tasks to maintain overall process performance due to changes in available technology or personnel. By leveraging the architectural models, the human system is designed to be adaptable to its anticipated operating environment.

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Keywords: Human View; System Architecture; Socio-technical Analysis

1. Introduction

An architecture framework is a set of models that organize information about the components and relationships of a complex system. These models are grouped into Viewpoints that represents different perspectives of the system architecture. For example, the System Viewpoint focuses on the technical components of the system, while the Operational Viewpoint emphasizes the functionality of the system. As systems have transitioned to more information focused, or networked systems, architecture frameworks have included additional viewpoints that represent the Data and Information perspectives [1]. However, the shift to network enabled systems also identified the need to capture the human requirements in the architecture framework: Network enabled systems rely on people and processes foremost, and then on technology. The types of human and organizational relationships that facilitate a successful networked system need to be defined at the architecture level so that technological capabilities are matched with organizational abilities, improving the social factors that have been shown to be barriers to information sharing [2].

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The Human View Architecture was developed in order to augment existing architectural frameworks with additional information relevant to the human in the system. Its goal was to capture the human system requirements that facilitate the network enabled processes [3]. The Human View was purposely designed to "fit" into existing architecture frameworks and to establish relationships with models from other viewpoints, especially the System and Operational Viewpoints. The goal of this research is to employ the Human View to identify the social-technical boundaries of the system and perform analyses at this junction**.**

2. The Human Viewpoint

The Human View contains seven static models that include different aspects of the human element, such as roles, tasks, constraints, training and metrics, as shown in Table 1. (Examples of each of the models indicated in Table 1 can be found in [3]). It also includes a human dynamics component to capture information pertinent to the behaviour of the human system under design. These Human View models are used to collect and organize social parameters in order to understand the way that humans interact with other elements of the system. Socio-technical systems are associated with the interaction of operators and technology through work processes [4]; the Human View products capture the human operator activities and coordination required to accomplish the work process objectives.

Table 1. Human View models [3]

Product	*Name*	*Description*
HV-A	*Concept*	*A conceptual, high-level representation of the human component of the enterprise architecture framework.*
HV-B	*Contraints*	*Sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.*
HV-C	*Tasks*	*Descriptions the human-specific activities in the system.*
HV-D	*Roles*	*Descriptions of the roles that have been defined for the humans interacting with the system.*
HV-E	*Human Network*	*The human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.*
HV-F	*Training*	*A detailed accounting of how training requirements, strategy, and implementation will impact the human.*
HV-G	*Metrics*	*A repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other Human View elements.*
HV-H	*Human Dynamics*	*Dynamic aspects of human system components defined in other views.*

The social component, captured in the Human View, often employs specific technologies during the completion of tasks that compose the work process. This relationship between the Human View and the surrounding Operational (OV) and System (SV) Viewpoint models, which capture system information, is shown in Figure 1. (For the specific content of each of the OV and SV models indicated in Figure 1, see [1]). For example, the SV-1, The System Interface Description provides information about the technologies used in the system. The link between the HV-C (Tasks) to the SV-1 provides a way to identify the technologies used for each of the tasks identified in the HV-C. Likewise the link from the HV-C to the Operational Activities, OV-5, indicates the higher level functions the human tasks support. The Human View models are "nested" within the greater system architecture framework, which provides the opportunity to perform a socio-technical analysis. The socio-technical analysis helps understand how the people, technology, and work process come together as a comprehensive system and identify social and technical limitations.

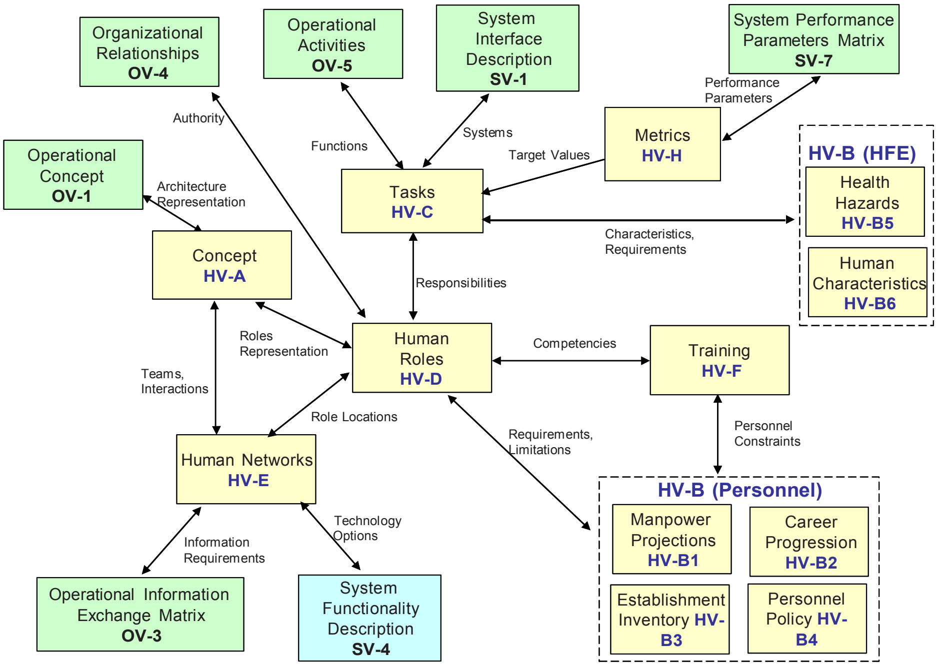

Fig 1. Relationship of Human View with surrounding architecture framework models

3. Socio-technical systems analysis

Socio-technical analysis is concerned with the fit of the technology and the human dimensions of a work process. In an information organization, the work process is often decision-based, and desired outcomes drive the choice and use of technology. Two types of socio-technical analyses based on the Human View framework are explored. The first is the analysis of a single key thread, or the sequential execution of a set of tasks, in order to identify the accompanying indicators and risks. The second analysis examines a single task in the key thread to identify alternative human and/or technology assignments to ameliorate the risk at the node. These two analyses used in conjunction address issues about dependence between socio-technical elements and suggest alternative configurations.

3.1 Key thread analysis

The human-centered tasks in a work process are described in terms of a sequence diagram called a key thread. The key thread is derived, usually in response to a given scenario, by tracing the launched tasks step by step. Various key threads are generated, each associated with a particular scenario, with the cumulative result ideally spanning the operational space of the system and used to identify shortfalls and redundancies [5]. For a socio- technical analysis, after the sequence of tasks in the key thread, representing the work process, is identified, each task can be categorized as a human centric (decision) or technology assisted task. This gives an indication of how a given sequence of tasks will perform, and the implications of changes to both the human and/or technology on the process outcomes.

An example of a key thread is shown in Figure 2. This figure represents the work process, "Create Assigned Slides", which is one of several sub processes of the Commander' Daily Update Brief process [6]. This process is in place in virtually every US military command. The Commander’s Daily Brief provides a morning update regarding the readiness and operational assets throughout the command. The work process that produces the brief includes analyzing data sources, creating Microsoft Power Point slides, and numerous review cycles. Coalescing the information for the brief typically requires multiple staff personnel and numerous reviewers from various functional areas to develop a series of Power Point slides that are organized into a single presentation that is catered to the commander's information requirements [5].

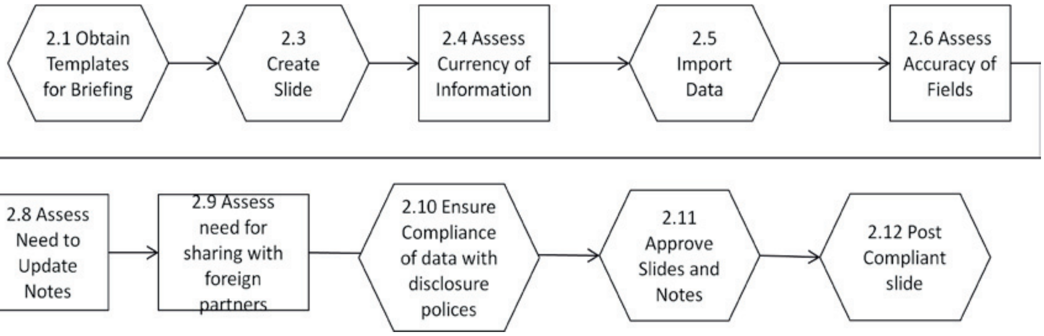

Fig 2. Key thread for "Create Assigned Slides"

In the figure, the hexagon shapes represent the technology assisted tasks. The technology that supports each of these tasks is found by following the relationships in Figure 1, from the HV-C (Tasks) to the SV-1 (System Interfaces). The data stored in the SV-1 indicates the technology used to complete these tasks, as well as any limitations. Likewise, the human decision nodes are represented by squares. Again using the relationships in Figure 1, the impact of human constraints are indicated by the data stored in the HV-BI (Human Constraints). Finally, the outcomes of the human work process will be evaluated by the metrics stored in the HV-G (Metrics). The key thread follows the process path from start to finish, identifying nodes as either human, or technology supported. By using information for each node stored in the surrounding architectural products, those nodes with problematic limitations that may be at risk to impact the process outcomes can be identified and further investigated with a node analysis.

3.2 Node analysis

In contrast to a key thread, which follows a work process from start to finish, the node analysis centres on a task that has conditions that influences the choice of paths or outcomes in the work process. The analysis highlights the lack of robustness of the socio-technical system at that point and emphasizes the shifts in reliance between technology and people. In the Human View approach, it focuses on identifying the limitations that may impact outcomes further in the work process. Since the Human View models captures the relationships across the socio-technical boundary, it can suggest alternatives that might help mitigate the risk and reduce the impact.

An example of a node analysis of a technology assisted node is shown in Figure 3. The node "Import Data", part of the key thread shown Figure 2, is expanded by including information captured in the neighbouring architecture products. The items of interest for this node, as shown in the figure, are the Commander's Guidance (from HV-A Concept of Operations), the assigned role (from HV-D Role), and the technology (from SV-1 System Interfaces). There is a known limitation for the technology "SIPRNET" as *Lack of Connection to Sources.* In order to maintain the timeliness of this work process, an alternative system can be identified. The Integrated Interactive Data Briefing Tool (IIDBT), an automated data gathering process using Web services that pull data directly from authoritative sources, is an alternative when connections to the SIPRNET are unavailable. This can be mapped to the task through the relationship to the SV-1 and allows for accurate information to still be provided in a timely manner.

Similarly, a node analysis of the "Assess need for sharing with foreign partners" task can be completed (not shown). In this case the relevant data elements are from the Commander's Guidance: *Info released to partners*, and the Role: *CFMCC Staff*. This is a human focused node with implications when the *Development Schedule not Followed*. In this case, the Special Security Officer (SSO), the role assigned to the subsequent step, can also perform this task concurrently with his assigned task in the work process. Again, this allows the process to continue to move forward in a timely manner and meet the requirements of compliant information.

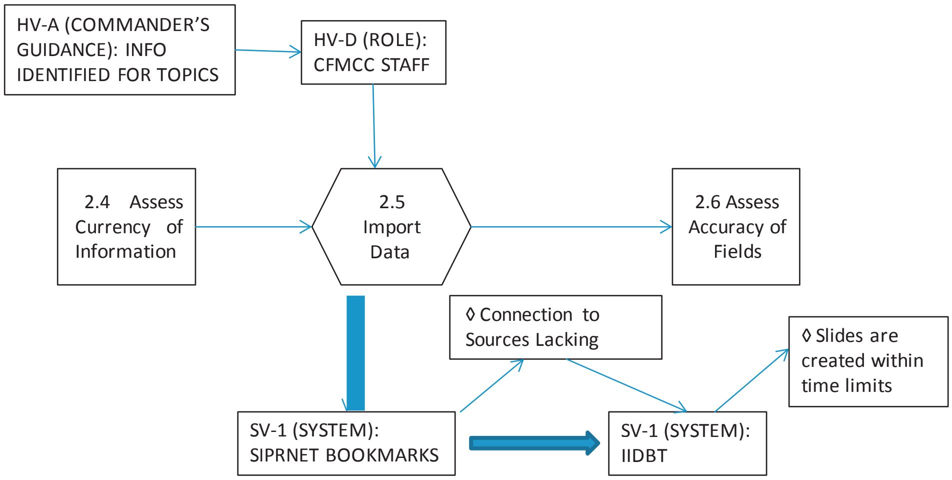

Fig 3. Node analysis of a technology assisted node

The node analysis looks at select nodes, those identified in the key thread analysis as having potential risk factors (through specified limitations), and identifies the corresponding architectural elements that contribute or are impacted by the risk. It then suggests alternative "states" that can be assumed to mitigate the risk when it is present in the environment.

4. Designing for adaptability

By combining the key thread and node analyses, a transition graph is created that illustrates the alternative role and technology matches to offset known risks. Additionally, alternative task paths in the key thread are included to complete a matrix of possible states for the socio-technical system [7]. This provides a path for adaptability for the organization based on events in the operational environment.

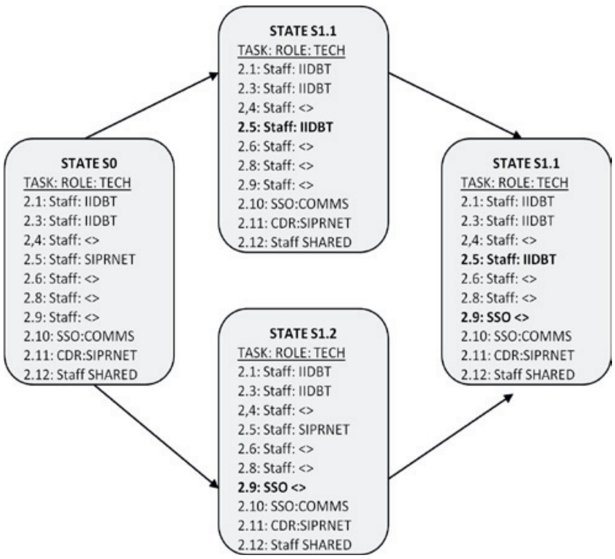

Fig 4. Transition Diagram (or lattice) for the socio-technical system

Figure 4 shows the transition graph, or lattice, for the Commander's Daily Update Brief example "Create Assigned Slides" sub process. The initial state is shown on the right hand side and labelled S0. Making changes to the technical part of the system, as described for the example in Figure 3, leads to the upper path to the state S1.1, i.e., switching to IIDBT; making changes to the social side of the system, such as switching the compliance review to the SSO, leads to the lower path to state S1.2. Combining both of these changes leads to a new state, S2, shown on the left hand side. By mapping out allowable states for both the social and technology aspects of the work process allows the system to stay congruent with changes in the organizational environment.

By combining the key thread analysis with a node analysis, the human view method provides a blue print through the transition graph to help the socio-technical organization react and adapt to the known risks in the environment. The congruence or fit of an organization is defined as the closeness between the task structure (the key thread) with both the role-task allocation and the distribution of resource capabilities (technology) among the organizational processes [8]. By defining the transition graph of allowable process states, the congruence with both the roles and technology is maintained.

5. Conclusion

This paper presented a methodology to perform a socio-technical analysis using the Human View architecture framework through a combination of key thread and node analyses. The key thread analysis identifies a sequence of tasks, usually in response to a specific scenario, that represents a work process. Problematic tasks are identified for a more detailed node analysis, which uses the relationships within the Human View to identify human and technology elements and constraints. The Human View leverages its position as "nested" within the system architecture to allow exploration at the socio-technical boundary. Limitations can be addressed by specifying alternative components that can then be included in the architecture models and thus become part of the system design. These alternative configurations, and the conditions that would activate the change, are captured in a transition graph. This allows the system to maintain congruence with the operational environment by allocating alternative roles and technologies that offset know risks that may occur and maintains the timeliness of the work process under differing conditions. Including the Human View not only completes the architecture framework but also provides a medium to complete socio-technical analyses that otherwise would not be possible.

References

1. DoDAF (2010). The DoDAF Architecture Framework Version 2.0, DoD Deputy Chief Information Officer, retrieved from http://cio-nii.defense.gov/sites/dodaf20/index.html.

2. Handley, H.A.H (2013). *A Network Model for Human Interoperability, Human Factors: The Journal of the Human Factors and Ergonomics Society, Forthcoming*.

3. Handley, H., & Smillie, R.. (2008). Architecture framework human view: The NATO Approach. *Systems Engineering*, 11(2), 156-164.

4. Cummings, T.G., & Worley, C.G.(1997). Organizational Development and Change, Cincinnati, OH: South-Western College Publishing

5. Ray, B.S. & Levis, A.H. (1993, June). *Crisis Management in the National Military Command Center (NMCC)* (GMU/C3I-135-P). Fairfax, VA: George Mason University, System Architectures Laboratory.

6.Handley, H.A.H & Heacox, N.J. (August 2005). Department of Defense Architectural Framework Products for the Commander's Daily Update Brief Process, Baseline Version. Technical Report. Pacific Science & Engineering Group, San Diego, CA.

7. Perdu, D. & Levis, A.H. (1998). ADaptation as a Morphing Process: A Methodology for the Design and Evalution of Adaptive ORganizational Structures. Journal of Computational & Mathematical Organization Theory, 4 (1) 5-41.

8. Levchuk, G.M., Kleinman, D.L., Ruan, S., KR. Pattipati, K.R. (2003). Congruence of Human Organizations and Missions: Theory versus data. *Proceedings of the 8th International Command and Control Research and Technology Symposium*, National Defense University, Washington, DC.