2017

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### Original Publication Citation
Mahmud, F., & Cotter, T. S. (2017). Human-intelligence/machine-intelligence decision governance: An analysis from ontological point of view. In E-H. Ng, B. Nepal, & E. Schott (Eds.), *Proceedings of the International Annual Conference of the American Society for Engineering Management.* (pp. 1-8). American Society for Engineering Management (ASEM).

*Proceedings of the American Society for Engineering Management 2017 International Annual Conference*
*E-H. Ng, B. Nepal, and E. Schott eds.*

# HUMAN-INTELLIGENCE/MACHINE-INTELLIGENCE DECISION GOVERNANCE: AN ANALYSIS FROM ONTOLOGICAL POINT OF VIEW

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## Abstract
The increasing CPU power and memory capacity of computers, and now computing appliances, in the 21st century has allowed accelerated integration of artificial intelligence (AI) into organizational processes and everyday life. Artificial intelligence can now be found in a wide range of organizational processes including medical diagnosis, automated stock trading, integrated robotic production systems, telecommunications routing systems, and automobile fuzzy logic controllers. Self-driving automobiles are just the latest extension of AI. This thrust of AI into organizations and everyday life rests on the AI community's unstated assumption that "…every aspect of human learning and intelligence could be so precisely described that it could be simulated in AI. With the exception of knowledge specific areas …, sixty years later the AI community is not close to coding global human intelligence into AI." (Cotter, 2015). Thus, in complex mission-environment situations it is therefore still debatable whether and when human or machine decision capacity should govern or when a joint human-intelligence/machine-intelligence (HI-MI) decision capacity is required. Most important, there has been no research into the governance and management of human-intelligent/machine-intelligent decision processes. To address this gap, research has been initiated into an HI-MI decision governance body of knowledge and discipline. This paper updates progress in one track of that research, specifically into establishing the ontological basis of HI-MI decision governance, which will form the theoretical foundation of a systemic HI-MI decision governance body of knowledge.

## Keywords
Decision Governance, Human Intelligence, Machine Intelligence, Artificial Intelligence.

## Introduction
Despite the continuing march toward implementing autonomous AI enabled machines, there has been little to no work in establishing an HI-MI decision governance body of knowledge. Thus, an HI-MI decision governance body of knowledge is needed. Artificial intelligence is still a long way from achieving human intelligence capabilities and current AI design treats humans as discontinuities in the autonomous system; however, when autonomous AI systems fail, control reverts to the human as the last resort to avoid system failure. The problem this research seeks to address is how the governance bodies of knowledge and best practices be integrated to develop a new body of knowledge for human-intelligence/machine-intelligence decision governance. As AI technology continues to advance, the key questions that we, the human being, should be looking for from systems perspective are (1) when should human decision capacity govern?, (2) when should machine decision capacity govern?, and (3) when should a joint human-machine decision capacity govern? This research, therefore, is to form a foundational ontological structure and axioms that succinctly will specify the HI-MI decision governance body of knowledge with the intent in mind to integrate into the decision making process of autonomous systems given varying mission critical situations in order to minimize the potential adverse outcomes or worse system failure.

## Background
There has been little to no research conducted toward creating an HI-MI decision governance ontology. Also there has been little to no research conducted toward establishment of governance ontologies in other disciplines. Search of the governance literature produced only the following few corporate, information technology, and knowledge governance taxonomies-

- Weimer, J. and Pape, J. (1999) proposed a system of corporate governance taxonomy based on eight characteristics: (1) prevailing firm concept and mission, (2) the board of directors system, (3) ability of salient stockholders to influence managerial decision making, (4) importance of stock markets in the relevant national economy, (5) presence or absence of external market controls on corporations, (6) ownership structure, (7) extent that executive compensation is dependent on corporate performance, and (8) the time horizon of economic relationships.
- Keenan, J. and Aggestam, M. (2001) overlaid Weimer and Pape's systems of corporate governance with an intellectual capital paradigm to create a composite taxonomy of corporate/intellectual-capital governance styles. The taxonomy mapped the use of intellectual capital along two dimensions: (1) Internal-External: Identifying and applying internal intellectual capital assets to set intra-organizational direction versus identifying and applying external intellectual capital assets to set extra-organizational direction and (2) Stability-Change: Identifying and applying intellectual capital assets embedded in institutionalized roles, structures, and processes to maintain stability versus identifying and applying intellectual capital assets oriented toward change and renewal.
- Donahue, J. (2004) proposed eight potential dimensions for corporate collaborative governance: (1) formal versus informal, (2) short versus long term duration, (3) specific issue versus broad focus, (4) public versus private institutional diversity, (5) valence defining the number of distinct entities linked together, (6) stable interests versus volatile interests, (7) allocation of the initiative among participants, and (8) problem-driven versus opportunity-driven.
- Hua, J., Miesing, P., and Li, M. (2006) identified two additional taxonomies to corporate governance based on China's transition from Communist Party ownership of all enterprises to a mix of market ownership and State-Owned Enterprises. They proposed a hybrid taxonomy of strong versus weak state-centered governance against a strong versus weak open-entrepreneurial systems governance.
- Von Nordenflycht, A. (2010) proposed a taxonomy of four types of knowledge-intensive firms based on capital intensity, knowledge intensity, and workforce professionalization: (1) technology developers, (2) Neo-professional service firms, (3) professional campuses, and (4) regulated professional service firms.
- Wilkin, C. and Chenhall, R. (2010) developed a taxonomy of research encompassing the focus areas of strategic alignment, risk management, resource management, and value delivery identified by the IT Governance Institute. They based their taxonomy on a review of 496 papers in ten IS/AIS and two Management Accounting journals over the period 1998–2008.
- Simonsson, M., Johnson, P., and Ekstedt, M. (2010) studied the relationship between IT governance maturity using the 34 IT processes defined in the Control Objectives for Information and related Technology (COBIT) taxonomy and actual IT governance from case studies of 35 organizations.
- Lampathaki, L., Charalabidis, Y., Passas, S., Osimo, D., and Melanie Bicking (2010) presented a taxonomy classifying research themes and research areas and subareas based on the European Union's CORDIS Information and Communications Technologies (ICT) Governance and Policy Modeling.
- De Haes, S., Van Grembergen, W., and Debreceny, R. (2013) noted that although it is a good-practice framework there has been limited academic research linking the core elements and principles of COBIT 5 to outcomes in the IT-related and general management literature.
- DeNardis, L. and Raymond, M. (2013) developed a disaggregated Internet governance taxonomy along with the dimensions of control of critical Internet resources, setting Internet standards, access and interconnection coordination, cyber security governance, information intermediation, and architecture-based intellectual property rights enforcement.

The general governance literature can be summarized as being comprised of taxonomic classifications of best practices dependent on the context and the researcher's objectives. Conversely, this research seeks to develop a universal HI-MI decision governance ontology as the basis for a body of knowledge in a universal set of HI-MI decision domains.

## Research Design/Methodology

We are establishing the initial ontological framework by applying some systematic and rigorous phases. Phase 1: Task 1: creating corpus of peer reviewed journal articles of systems, environmental, governmental, organizational, decision, knowledge, information, and data governance; Phase 1: Task 2: performing context analysis to identify structural commonalities and differences in the literature corpus; Phase 2: Task 1: in grounded theory, applying open coding to find concept classes/categories; Phase 2: Task 2: following SUMO ontological design, establishing seed classes/categories; Phase 2: Task 3: conduct parallel validation for taxonomic classes/categories; Phase 3: Task 1: in

grounded theory, RQDA (R statistical package for Qualitative Data Analysis) analysis to suggest axial coding to find concept relationships; Phase 3: Task 2: following SUMO ontological design, establish ontological relationships; Phase 3: Task 3: conduct parallel validation for ontological relationships; Phase 4: Task 1: in grounded theory, applying selective coding for concept refinement; Phase 4: Task 2: following SUMO ontological design, complete taxonomy-ontological refinement; Phase 4: Task 3: conduct parallel validation for taxonomy-ontological relationships; Phase 5: Task 1: cross-check against necessary and sufficient conditions for foundational ontology and foundational Body of Knowledge (BoK) for HI-MI decision governance.
A mixed research method is followed in quantitative analyses overlaid on a qualitative analysis framework.

## Data Collection

The data (text based) we are using comes from all the relevant literature within various domains as already mentioned. A rigorous search from peer reviewed journals, publications, conference presentations, and books have been reviewed to identify relevant literature for our research.

## Exploratory Text Mining Methodology

In order to build the necessary HI-MI decision governance ontological foundation, this research initiative is proceeding in four stages: (1) build a corpus of decision/governance research articles and standards, (2) text mining the corpus to develop an initial indication of important taxonomic terms, (3) conduct content analysis based on the identified important terms to build a basis for open coding the corpus, and (4) conduct grounded theory analysis to establish the theoretical basis of the HI-MI decision governance ontology. To date, an initial corpus has been built from 46 peer reviewed journal articles of systems, environmental, governmental, organizational, decision, knowledge, information, and data governance. Following the text mining taxonomy proposed by Miner, G., Elder, J., Fast, A., and Hill, T. (2012), text mining was applied in the AI and Machine Learning practice area of text analytics to extract term information and clustering within the literature related to decision governance. First, all articles were converted into ".txt" format. However, this conversion did not automatically omit all the extraneous words (journal header/footer or information related to the publication but not the body of work). Each text file was then manually cleaned to remove header and footer information before performing text mining using text mining package "tm" installed in statistical software R (version 3.1.3).
Standard cleaning procedures were followed to remove punctuation, numbers and English stop words, to convert all words to lower case, and to stem words. Two iterations of removing sparse terms were performed, and the sparse document term matrix was inspected to remove the following generic terms not directly related to decision governance: Iteration 1 – "also", "based", "can", "given", "however", "important", "many", "may", "new", "number", "one", "possible", "three", "thus", "two", "use", "used", "well", "will", and "within"; Iteration 2 – "consider", "discuss", "first", "follow", "increase", "involve", "like", "make", "mean", "point", "present", "provide", "take", "use", "way", "without", and "work."

## Exploratory Text Mining Results

After text mining, a bar plot of frequency versus word was created using the Euclidean distance method. The first bar plot was of words with frequency > 350 as shown in Exhibit 1.
The second bar plot was of words with frequency > 500 as shown in Exhibit 2. The bar plot frequency analyses identified the following most encountered words:

- Intelligence – 1,783 count.
- System – 1,192 count.
- Relation – 1,111 count.
- Test – 974 count.
- Model – 952 count.
- Technology – 900 count.

**Exhibit 1.** Frequency bar plot with frequency > 350.

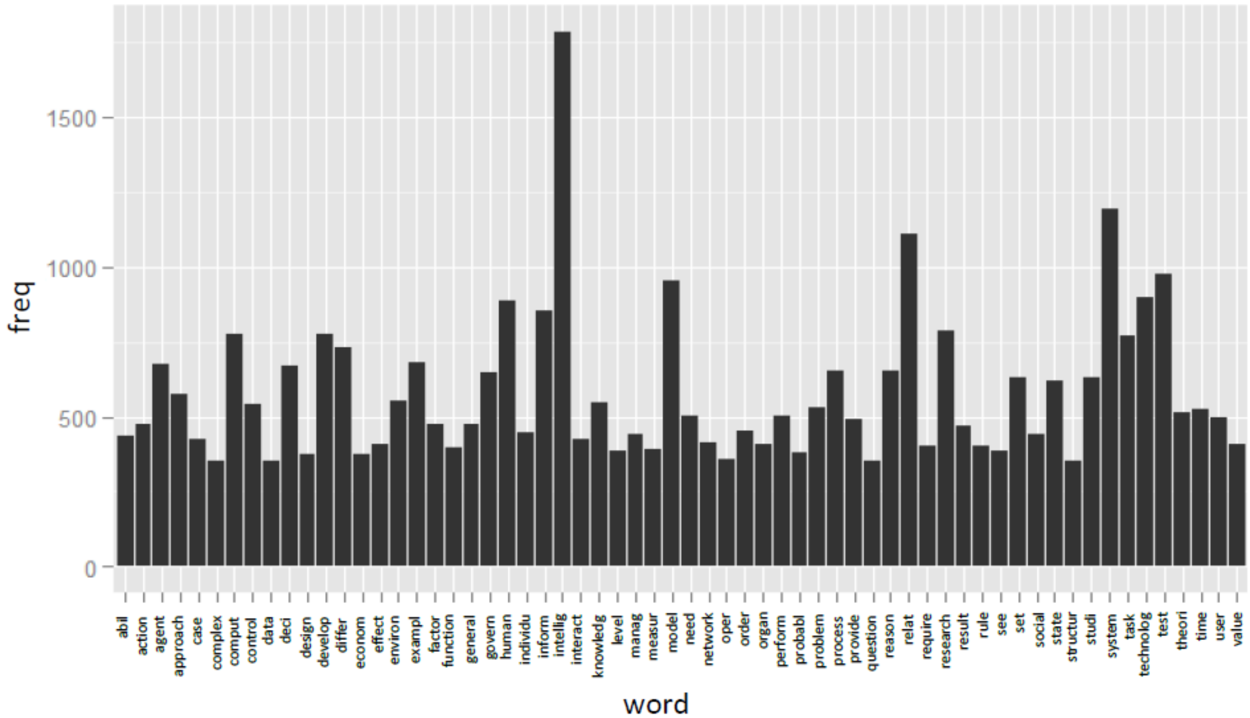



**Exhibit 2.** Frequency bar plot with frequency > 500.

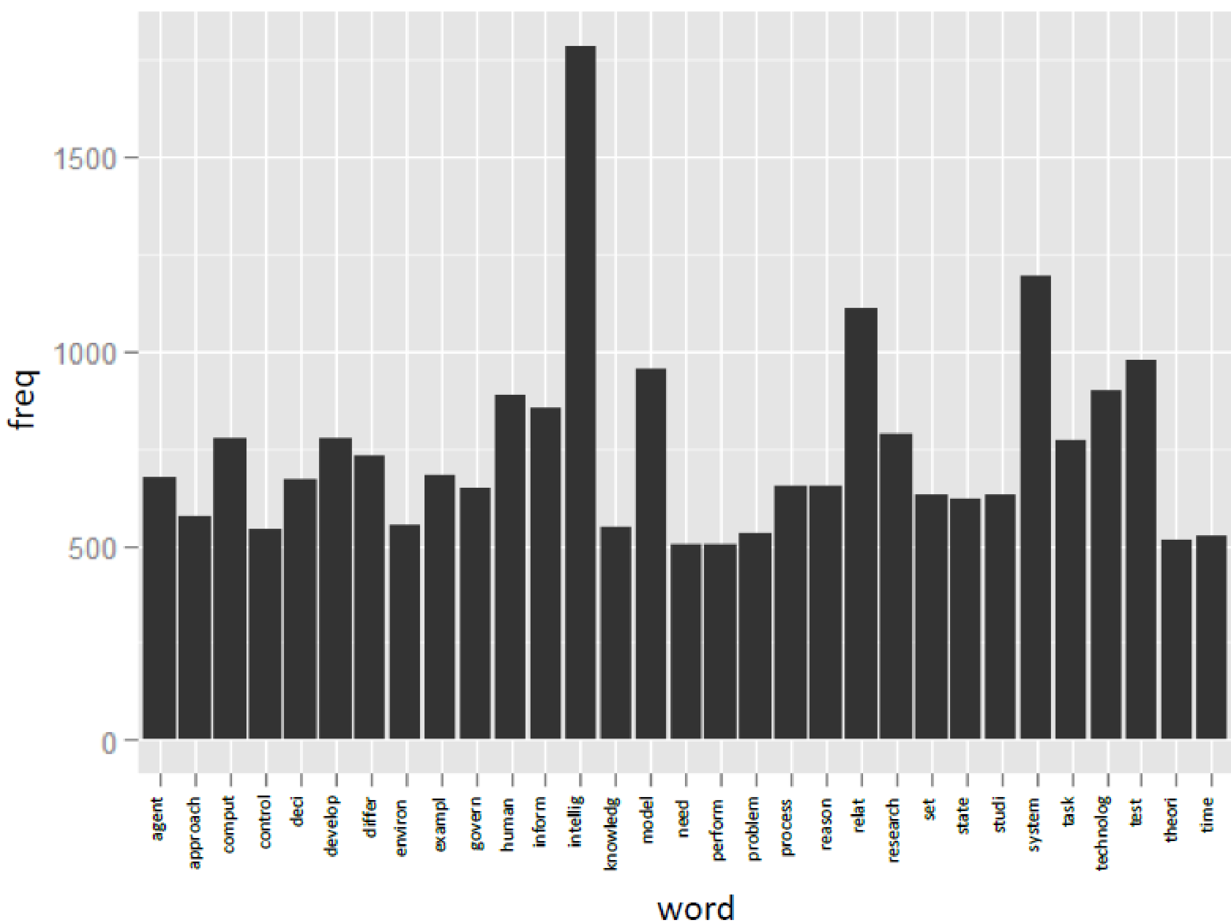
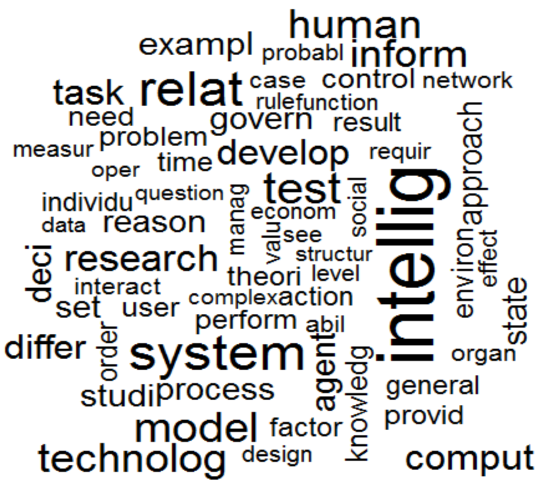
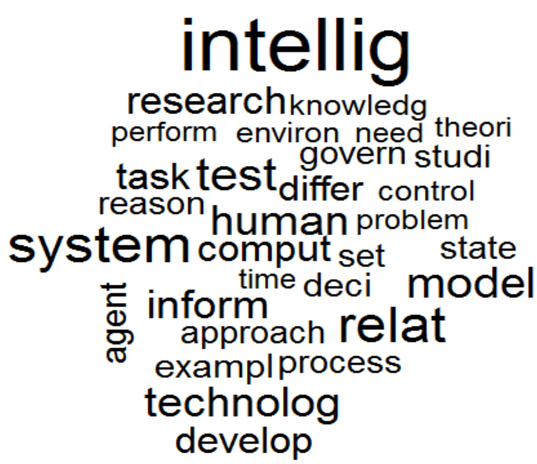


**Exhibit 3.** Word cloud with minimum frequency = 350.



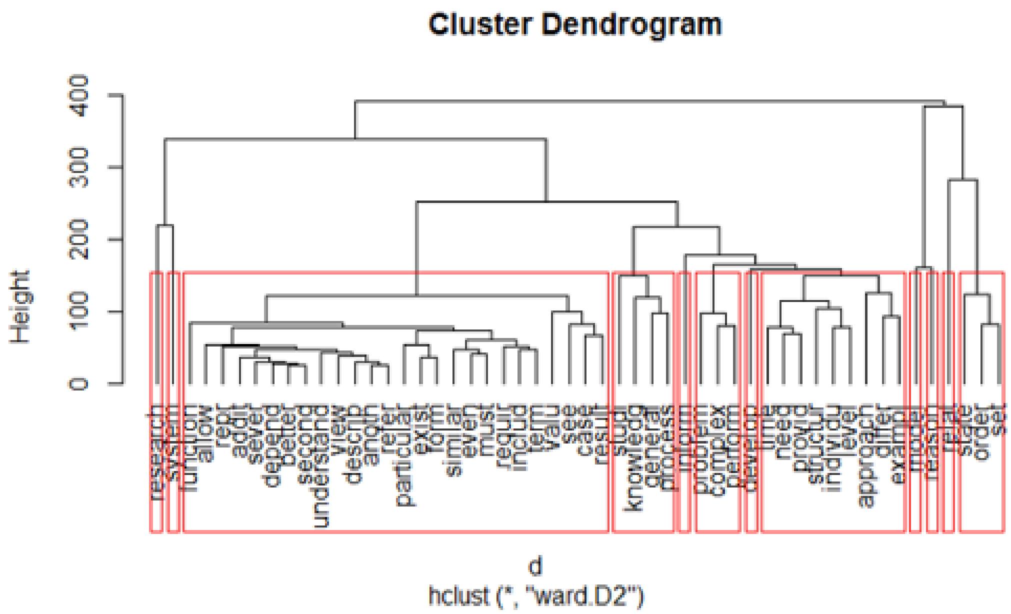

From frequency analyses and review of the relevant literature, we concluded that the primary focus appears to be on identifying, modeling, testing relations among systemic intelligence domains, and on building technological solutions to deploy decision/governance systems. This conclusion will have to be tested and verified with formal text analytics. In order to further visualize frequency relationships, text clouds were plotted with minimum frequencies = 350 and 500. These are presented in Exhibit 3 and Exhibit 4.

**Exhibit 4.** Word cloud with minimum frequency = 500.




To show potential taxonomic relationships, a Cluster Dendrogram with 15% sparse terms in 12 groups (Exhibit 5) and a Cluster Plot with k = 12 means (Exhibit 6) were plotted.

**Exhibit 5.** Cluster Dendrogram with 15% sparse terms in 12 groups.




As shown in Exhibit 5, the first two components explain 80.65% of the point variation. The Cluster Dendrogram suggests that methodology (words – research, development, and model) and structure (words – information, model, and system) form independent dimensions respectively.

**Exhibit 6.** Cluster plot with k = 12 means.

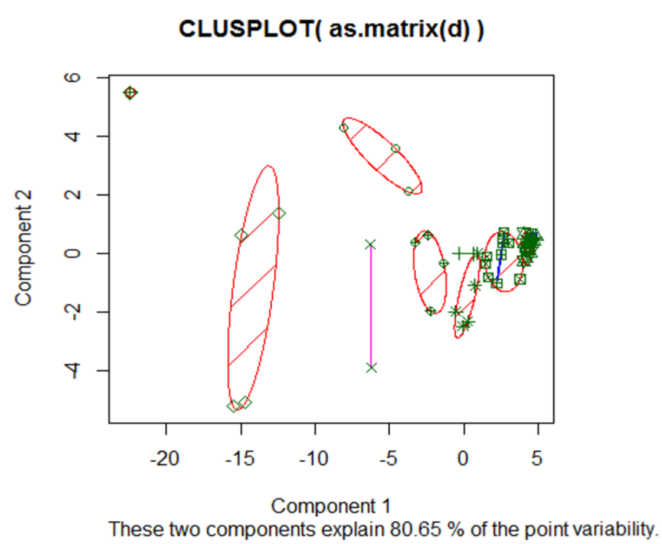
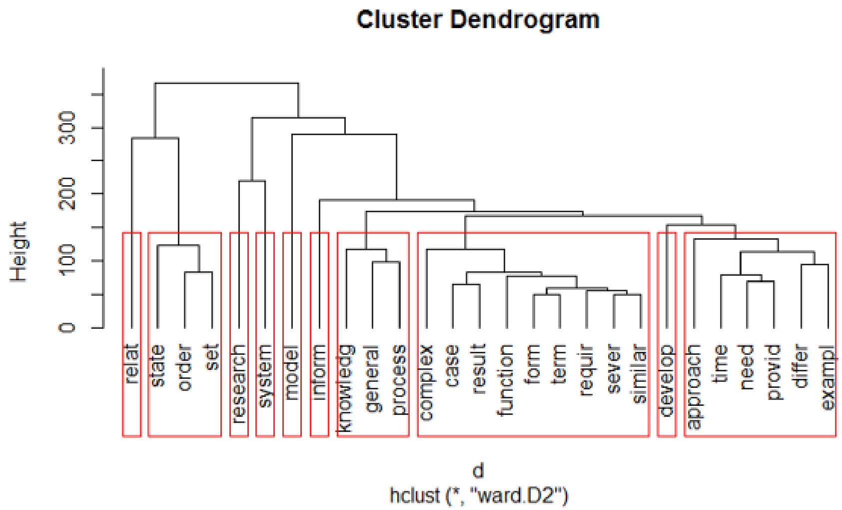


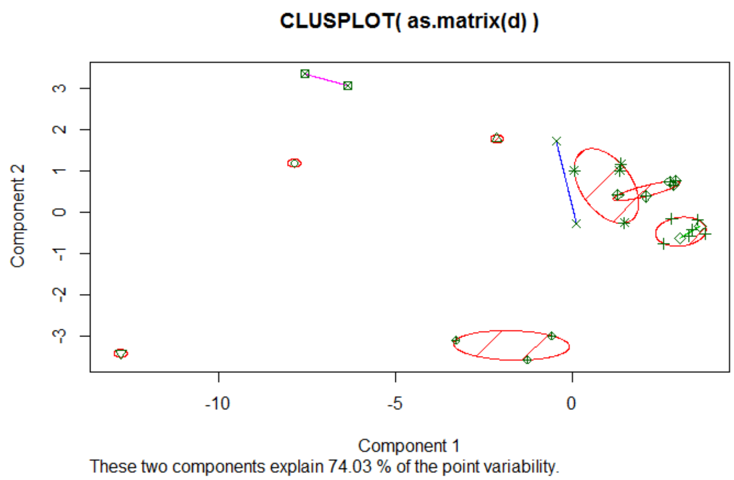
**Exhibit 7.** Cluster Dendrogram with 10% sparse terms in 10 groups.




The largest cluster tends to focus on relationship descriptions. To reduce the taxonomic dimensionality, a Cluster Dendrogram with 10% sparse terms in 10 groups (Exhibit 7) and a Cluster Plot with k = 10 means (Exhibit 8) were plotted.

As shown in Exhibit 7, the first two components still explain 74.03% of the point variation. The Cluster Dendrogram shows that the same methodology words (research, development, and model) appear as independent dimensions but that structure as a set of independent terms is describe by the words information, relations, and system. Since a system can be defined as a set of entities and their inter-relationships, the independent terms describing structure appear to be consistent. The largest cluster now appears to focus on decision/governance components. Interestingly, the highest frequency term "intelligence" did not appear in either Dendrogram. Again, these observations will have to be tested and verified with formal text analytics.

**Exhibit 8.** Cluster plot with k = 10 means.



## Continuing Research

Text mining analyses presented in this paper represent only exploratory findings toward building an HI-MI decision governance ontology. Literature search continues toward building a decision/governance literature corpus that is statistically representative of the population. Future research will include saturation and statistically formal text analytics to identify taxonomic dimensions and sub-dimensions. Content analysis will be performed in RQDA to identify structural commonalities and differences as the basis for open coding the corpus. Finally, axial coding will be performed to identify inter-relationships, and grounded theory analysis using the NVivo package will be conducted to establish the ontological, axiomatic, and theoretical basis for the HI-MI decision governance body of knowledge.

## References

Cotter, T. (2015). Research agenda into human-intelligence/machine-intelligence Governance. *Proceedings of the 2015 Annual ASEM Conference*.

De Haes, S., Van Grembergen, W., and Debreceny, R. (2013). COBIT 5 and Enterprise Governance of Information Technology: Building Blocks and Research Opportunities. *Jounral of Information Systems 27*, 307-324.

DeNardis, L. and Raymond, M. (2013). Thinking Clearly about Mutlistakeholder Internet Governance. *Proceedings of the Eighth Annual GigaNet Symposium*.

Donahue, J. (2004). *On Collaborative Governance*. Corporate Social Responsibility Initiative Working Paper No. 2. Cambridge, MA: John F. Kennedy School of Government, Harvard University.

Hua, J., Miesing, P., and Li, M. (2006). An Empirical Taxonomy of SOE Governance in Transitional China. *Journal of Management Governance 10*, 401-433.

Keenan, J. and Aggestam, M. (2001). Corporate Governance and Intellectual Capital: some conceptualizations. *Corporate Governance: An International Review 9(4)*, 259-275.

Lampathaki, L., Charalabidis, Y., Passas, S., Osimo, D., and Melanie Bicking. (2010). Defining a Taxonomy for Research Areas on ICT for Governance and Policy Modelling.

Miner, G., Elder, J., Fast, A., and Hill, T. (2012). *Practical Text Mining and Statistical Analysis for Non-structured Text Data Applications*. Philadelphia: Elsevier Science.

Simonsson, M., Johnson, P., and Ekstedt, M. (2010). The Effect of IT Governance Maturity on IT Governance Performance. *Information Systems Management 27*, 10-24.

Von Nordenflycht, A. (2010). What Is A Professional Service Firm? Toward a Theory and Taxonomy of Knowledge-Intensive Firms. *Academy of Management Review 35*, 155-174.

Weimer, J. and Pape, J. (1999). A Taxonomy of Systems of Corporate Governance. *Corporate Governance: An International Review 7(2)*, 152-166.

Wilkin, C. and Chenhall, R. (2010). A Review of IT Governance: A Taxonomy to Inform Accounting Information Systems. *Journal of Information Systems 24*, 107-146.

SUMO. Suggested Upper Merged Ontology. Retrieved July 12, 2017 from http://www.adampease.org/OP/

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