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Structuring the Organization for Strategic Fit

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Managerial Relevance Statement

How does a firm cope with multiple interdependent, sometimes conflicting strategic themes, themes such as standardization for efficient aggregation and variation for regional adaptation? It is known that interacting strategic themes, when integrated as a coherent whole, lead to a lasting competitive advantage. But then the question is how? This paper develops a model of an organization to gain insights on this key challenge of strategy integration. First, the model suggests that managers should adopt a radically different view of an organization as a dynamic aggregation of interacting coordination networks each of which addresses a distinct strategic theme. Second, the top management must be able to locate in the organization a special class of managers called *thematic integrators*, who engage in multiple coordination networks with conflicting demands (the model can help identify thematic integrators). Thematic integrators must be mentored to develop a proper mindset to embrace conflicting themes. The model also suggests that boundary-spanning strategic initiatives tend to derive *emergent coordination structures* in the organization. Such structural by-products in turn reconfigure and enrich the network aggregation structure for enhanced strategy integration. The top management can facilitate this dynamic process of organizational reconfiguration by creating an environment conducive to boundary-spanning strategic collaboration.

Abstract

Competitive advantage derives from effective management of interdependent, sometimes conflicting strategic themes for superior fit. We develop a graph-theoretic formalism called *thematic networks* in order to study strategic fit by capturing and analyzing *organizational manifestations* of interacting strategic themes. A critical property of thematic networks is that they can be overlaid one on the other to construct increasingly more complex thematic networks. Consequently, resulting overlay structures can capture interacting strategic themes far beyond the extent possible in conventional overlay structures known in the literature. Another critical property of thematic networks is their duality. Namely a thematic network can be seen as a network of positions (the positional view) and also as a network of themes of strategically significant tasks (the thematic view). We show that one view is the dual of the other. We interpret this duality theorem through Giddens' structuration theory, and present a perspective on the organizational dynamics capable of reconfiguring its structural environment for superior strategic fit. In addition, given the importance of conventional reporting structures, we identify a class of thematic networks for which reporting hierarchies exist. We show that reporting hierarchies can be directly derived from the positional view, or indirectly through the thematic view, using the duality results.

Key words: strategic fit, strategic themes, overlay structure, coordination, structuration theory

1. Introduction

In recent years, the strategic implication of interacting tasks and practices in managerial settings has been vigorously investigated (Milgrom and Roberts 1995, Porter 1996, Rivkin 2000, Siggelkow 2002, Rivkin and Siggelkow 2007, Porter and Siggelkow 2008). A recurrent theme in these studies is the structural nature of interacting tasks or the idea that the whole is not reducible to a mere collection of its parts. For instance, Porter states: "The competitive value of individual activities cannot be separated from the whole. … Competitive advantage grows out of the entire system of activities" (1996, p.72~73). Following Porter (1996), we use the term *strategic fit* to refer to the fit among strategically significant tasks that may collectively produce competitive advantage. This paper addresses the long-standing challenge of furthering our understanding of strategic fit and how it generates competitive advantage of the structural nature.

There are two broad categories of theoretical studies on strategic fit and task interactions. One aims to directly capture and analyze the collective performance of interacting tasks either by mathematical characterization of the performance (Milgrom and Roberts 1990, 1995) or through computational simulation of the performance (Rivkin 2000, Rivkin and Siggelkow 2007). In these studies, the collective performance of interacting tasks is captured by abstracting from actual forms of individual interactions. The other category of studies, on the other hand, intends to explicitly represent actual forms of interdependence among individual tasks. These works go beyond simple predecessor-successor relationships among tasks and capture some degree or aspect of interdependence complexity: e.g., "coupled tasks" (Eppinger et al. 1994), "interdependence degree" (Levitt et al. 1999), "fit dependencies" (Malone et al. 1999), and "task interaction metagraphs" (Basu and Blanning 2000). Overall, however, it is not clear at this point how such explicit representations can capture the level of task interaction complexity which is sufficient for studying all forms of strategic fit.

This paper sets the stage for a complementary approach to the study of strategic fit. Namely, instead of directly studying tasks and their interactions, the approach aims to capture and analyze their *organizational manifestations*. Organizational manifestations of tasks and their interactions refer to a collection of organizational constructs that carry out the tasks and manage their interactions for strategic fit. We call such a collection an *organizational configuration*. As organizational configurations are likely to be strategy-specific, it is desirable to have a common representational scheme for a variety of organizational configurations. We use the term an *organizational domain* to refer to such a representational scheme.

A simple example of an organizational domain is “structured networks” of Goold and Campbell (2002). The representational scheme of structured networks is a collection of concepts consisting of eight types of organizational units such as “business units”, “functional units”, “overlay units”, and “project units”, four attributes associated with each type of units, namely “responsibilities”, “accountabilities”, “reporting relationships” and “lateral relationships” and other sub-concepts such as five different types of “lateral relationships”. The collection of these concepts is intended to serve as a “language” for organization design (Goold and Campbell 2002, p.13). Specific organization designs given in this language correspond to our notion of organizational configurations. To see how tasks and their interactions can be mapped into constructs in this Goold-Campbell domain, consider some high-level tasks such as “modular product design” and “low-cost manufacturing”. These tasks can be probably allocated to certain “functional units”. The interaction of these two tasks might then be facilitated by a “project unit” overlaid on the two functional units, and non-structural means of linkage such as “overlapping responsibilities” and “shared accountabilities” (Goold and Campbell 2002, p. 121-126).

While the language of structured networks may serve as an aid for organization design, as originally intended, it has some shortcomings as a domain for analysis of strategic fit. Most notable is the fact that it comes with a fixed, non-extensible vocabulary. Organizations may face situations of building strategic fit that require organizational constructs outside the predefined vocabulary. In order to cope with such unforeseeable variations of organizational configurations, organizational domains need to be extensible. It is worth noting here that an area of discipline well-experienced with extensible domains is the study of programming language semantics (Gunter and Scott 1990, Stoltenberg-Hansen et al. 1994). In fact, the idea of designing a space, or a domain, and using it to interpret and characterize entities external to the space is from computational domain theory of programming languages. A domain for a programming language is a mathematical space through which syntactic constructs in the language are given precise computational meanings. Similarly, we would like to have an extensible domain through which “activity constructs” such as those in Porter’s “activity-system maps” (1996) can be given organizational meanings.

This paper offers a formal basis, called *thematic networks*, for building such organizational domains. As a mathematical formalism, thematic networks are extensible. But thematic networks do not represent a complete organizational domain. Unlike semantic domains for programming languages, where complete mathematical specification is desirable for precise language implementation, we think that organizational domains benefit from having rich informal contents not necessarily amenable to mathematical formalization. But it is still good to have an extensible formal core in an organizational domain. For an outline of thematic networks as such a formal core, we introduce three key features of thematic networks and motivations behind those features.

Thematic representation of positions. A thematic network is a collection of positions with certain relationships among them. Each position in a thematic network is given as a set of *themes* of tasks to which the position is committed. There are two types of themes, *support themes* and *lead themes*. A position has a support theme when it is committed to a task in which it plays a supportive role. A position has a lead theme when it is committed to a task in which it plays a leading or coordinating role. As an example, consider a matrix manager having a country manager and a business manager as his two bosses. The matrix manager is then likely to have a support theme for a task his country manager coordinates and another support theme for a task his business manager leads, in addition to various lead themes for the tasks the matrix manager himself overseas. Thus, the matrix manager must be mentally prepared to manage multiple themes of task commitment, particularly the two support themes along the business and country lines which often demand conflicting outcomes. This thematic articulation of positions is aligned with one executive’s observation on matrix management: “The challenge is not so much to build a matrix structure as it is to create a matrix in the minds of our managers” (Bartlett and Ghoshal 1990). More fundamentally, the thematic view of positions is closely related to Giddens' structuration theory (Giddens 1984) and managerial insights gained as it is applied to organizational settings (Orlikowski 2000). We will come back to this point in the discussion section.

Overlay structures. Two or more thematic networks can be overlaid one on the other, through positions commonly appearing in those networks. The resulting overlay aggregation is again a thematic network. This aggregation process can be applied successively to construct increasingly more complex thematic networks. Thus, aggregated thematic networks capture overlay structures of varying complexity. These overlay structures are structural means of facilitating interactions among different, possibly distant, organizational units at various levels of the organization. Organizational constructs of this kind are extensively discussed in the literature: "matrix structures" (Davis and Lawrence 1977), "lateral processes" (Galbraith 1973), "liaison overlay structure" (Mintzberg 1979), and "overlay units" (Goold and Campbell 2002). While overlay structures in the literature tend to be formal, deliberate constructs, in thematic networks, they can also be informal, emergent structures. In short, thematic networks are intended to offer rich structural settings for organizationally mapping tasks and their interactions.

Extensibility. As touched upon earlier, extensibility is desirable as organizations frequently devise new structures for enhanced interaction and fit among organizationally distributed tasks. Such new structures can be deliberately designed and implemented. But they can also emerge at various levels of the organization without top-down initiatives. For instance, Kellogg et al. (2006) reports on "emergent coordination structure" that facilitates a cross-boundary team project. Fenton and Pettigrew (2000) discuss a case where an informal network was initially developed across national borders and later established as a formal organizational unit. These emergent structures, as they are not planned, may possibly represent new types of constructs, and hence reinforce the motivation for extensibility. Furthermore, on the conceptual side, we have a vast accumulation of literature on the dynamic nature of competitive advantage and organizational forms (e.g., Volberda 1996, Brown and Eisenhardt 1997, Teece et al. 1997, Eisenhardt and Martin 2000, Rindova and Kotha 2001). In coping with the demand on organizations to implement new sources of competitive advantage, particularly new forms of task interaction and strategic fit, thematic networks, within the bound of their expressiveness as a mathematical formalism, can represent a large variety of organizational configurations, possibly including those not yet encountered in the business practice.

Mathematically, thematic networks are closely related to certain forms of networks in the study of social networks such as “multirelational social networks” (Pattison 1993, p.8~11) and “multigraphs” (Wasserman and Faust 1994, p.145). All of these networks including thematic networks are interested in multiple types of relationships among members of the network. Additionally, however, thematic networks are equipped with a new structure, namely a *partial order*[1] defined on *types* of relationships, and hence they can be seen as an extension of multigraphs. We will elaborate on this in the discussion section.

The remaining part of the paper is organized as follows. Section 2 defines thematic networks and gives a few illustrative examples. In § 3, a formal account of overlay structures is given through a certain network union operation. Section 4 introduces two quotient constructs, which represent positional and thematic views of thematic networks. The duality results on these two views are also given in § 4. Section 5 identifies a class of thematic networks for which reporting hierarchies exist, and shows that those reporting hierarchies can be found through the positional view of a thematic network, or indirectly through the thematic view, using the duality results established in § 4 . Section 6 discusses the significance of these results as well as how thematic networks further our understanding of strategic fit. Some concluding remarks are given in § 7.

2. Thematic Networks

As stated earlier, a thematic network is essentially a collection of positions with certain relationships among them. Recall that our aim is to establish a formal basis for organizationally mapping tasks and their interactions. Thus, “relationships” among positions of our interest are task-oriented. Consider tasks

A and B. Suppose, for instance, the scope of task A contains the scope of task B either partially or fully. Or the concern of task A subsumes the concern of task B either partially or fully. More concretely, task B might be a component subtask of task A (full containment), or task A might be a coordination task with its coordination span partially including task B (partial subsumption). In such situations, we say that task B *attends to* task A.

We now consider relationships among positions in terms of relationships among tasks of those positions. Given positions p and q where a task that p is in charge of attends to a task that q is in charge of, we say p *answers to* q, assuming that p commits to support the task of q. Such "answer to" relationships can be formal as in reporting relationships or informal as in many cases of lateral relationships. We also wish to capture situations where a self-coordinating team accomplishes its task through lateral communication and collaboration without answering to anyone. In order to include self-coordinating teams in a uniform notation, among other reasons of notational uniformity, we introduce a notational convention called *empty positions*. Thus, members of a self-coordinating team answer to a common empty position. We now give a formal definition of thematic networks.

Definition 1. A *thematic network* is a tuple (P, M, R, Z) where

- P is a set of *positions*;
- M is a set of *themes*;
- R is a set of ordered pairs of the form $(p,a) \to (q,a)$ where $p,q \in P$, $p \neq q$ and $a \in M$. When R has a pair $(p,a) \to (q,a)$, we say that p *answers to* q *through* a. We call pairs in R *answer relationships*. When p answers to q through a, a is a *support theme* of p and it is a *lead theme* of q. We assume that for each $p \in P$, the set of support themes of p is disjoint from the set of lead themes of p; and

[1] A *partial order* on a set S is a binary relation $\leq$ on S such that for all $x, y, z \in S$, $x \leq x$ (reflexivity), $x \leq y$ and $y \leq x$ imply $x = y$ (antisymmetry), and $x \leq y$ and $y \leq z$ imply $x \leq z$ (transitivity). For an introduction to partial orders and related concepts in order theory, see, for instance, Davey and Priestley (2002).

- Z is a subset of P, consisting of designated positions called *empty positions*.

Figures 1, 2 and 3 are illustrative examples of thematic networks. As in these examples, we follow some notational conventions. Throughout this paper, letters p, q, and r, with or without subscripts, denote positions, while a, b, c, and d, with or without subscripts, represent themes. For formal simplicity, we assume that an empty position has exactly one theme, and we use φ, subscripted with its theme, to denote an empty position. Lines in the thematic networks in the Figures represent answer relationships. Although lines do not have arrowheads to indicate asymmetrical answer relationships, the convention adopted is that when there is a line from a position to another position upward, the first position answers to the second position. Thus, for instance, in Figure 1, p_3 answers to p_1, that in turn answers to p_0. Regarding themes, Figure 1 shows two collections of themes, namely $\{a_0, a_1, a_2, a_3\}$ and $\{b_1, b_2, b_3\}$. In general, collections of related themes are also called themes, and they typically represent higher-level strategic themes. Sometimes, the term *dimension* is used to refer to specific high-level themes such as "business" and "geography". In Figure 1, $\{a_0, a_1, a_2, a_3\}$ represents the business dimension while $\{b_1, b_2, b_3\}$ specifies the geography dimension.

Figure 1 is a simplified illustration of the practice at DuPont where many managers are given dual responsibilities along the business and geography dimensions (Galbraith 2000, p.105-106). In the DuPont case, the business dimension is the primary dimension, and the geography dimension is the secondary dimension, which is designed to be a partial mirror image of the business dimension. At DuPont, two of the business unit executives located in Europe and Asia are expected to develop regional ties with business communities, governments and politicians. Thus these executives, which correspond to p_1 and p_2 in Figure 1, have business-geography dual responsibilities. At a lower level of the organization, site managers in particular locations (e.g., a manufacturing site in Luxembourg) serve as country managers (e.g., the Luxembourg country manager). Thus these site managers, which correspond to p_3, p_5, p_6 and p_7 in Figure 1, also have business-geography dual responsibilities. Note that the business and geography dimensions at

DuPont are coordinated not through matrix structure, but by the arrangement where the secondary dimension is a partial mirror image of the primary dimension. This mirror-image coordination is difficult to capture without explicitly introducing themes. Note also that it follows from the definition of thematic networks and the diagrammatical convention of answer relationships that position p_1, for instance, has support themes a_1 and b_1, and lead themes a_2 and b_2.

Figure 1 A Thematic Network for Partial-Mirror Coordination

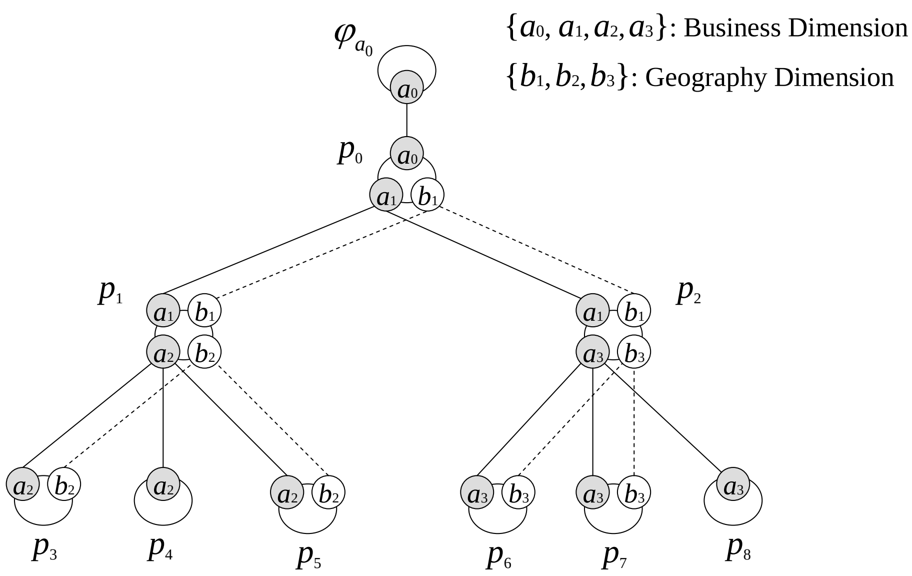
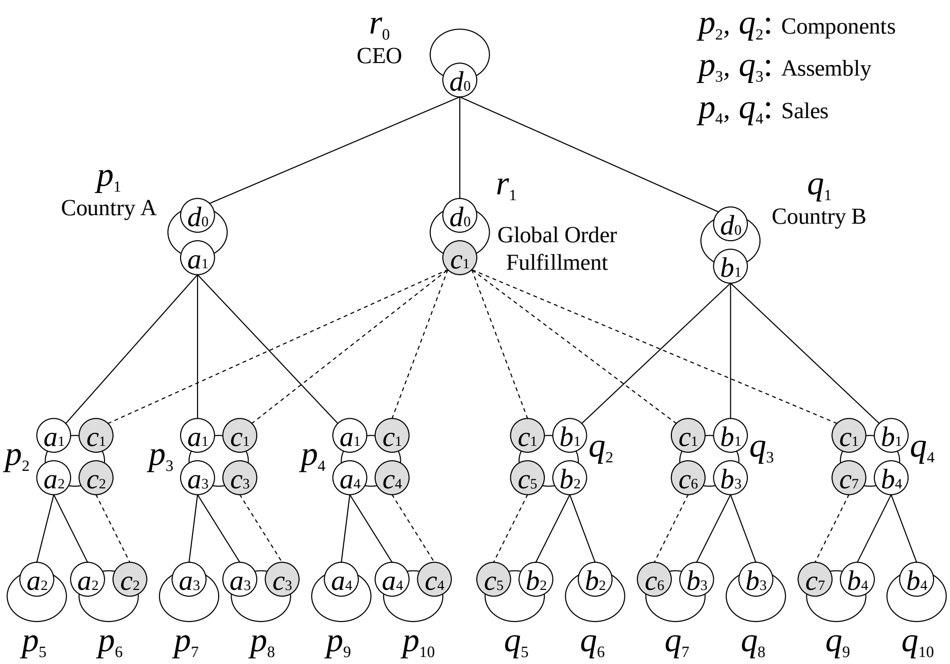


Figure 2 illustrates a coordination structure at a U.S. medical equipment company (Galbraith 2000, p.167-174). The collection $\{c_1, c_2, \cdots, c_7\}$ specifies the strategic theme of global order fulfillment. In this case, structurally homogeneous units located in countries A and B are coordinated for global efficiency through an extensive, cross-functional, cross-regional team. These country units are specialized for specific product lines, but these product lines are for global distribution. Hence, these units must be coordinated for order aggregation, production planning, scale-sensitive shared components, etc. The coordinating team, thus, has a large diversity, consisting of members from different regions, different functions (such as components, assembly and sales), and the headquarters. Some coordination relationships are maintained virtually through computer-mediated communications.

Figure 2 A Thematic Network for Indirect Homogeneous Coordination



In Figure 3, unlike the mirror-image coordination of the DuPont case, the business dimension and the geography dimension are more clearly separate and represent two distinct organizational units. The two units show, however, considerable overlay for cross-dimensional coordination. Note that this cross-dimensional coordination structure is considerably different from the conventional matrix structure. For instance, Business Unit 1 has much stronger affiliation with Country A than with Country B, as opposed to more balanced geographic ties as in the conventional matrix arrangement. Thematic networks are sufficiently expressive to catch such structural differences. Now, in comparison to the case in Figure 2, the coordination structure in Figure 3 relies on no separate coordination mechanism such as the global order fulfillment unit in Figure 2. The business and the geography dimensions in Figure 3 are directly interlinked. Now reviewing the examples in Figures 1, 2 and 3, note that they illustrate three rather distinct coordination structures, all captured in the uniform representation scheme of thematic networks.

Figure 3 A Thematic Network for Direct Heterogeneous Coordination

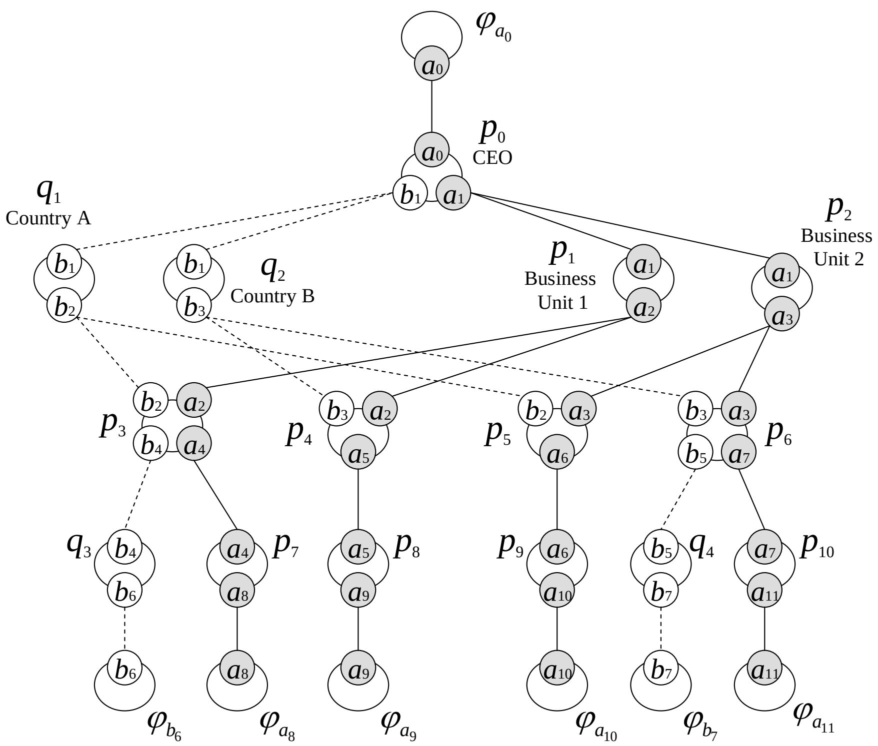
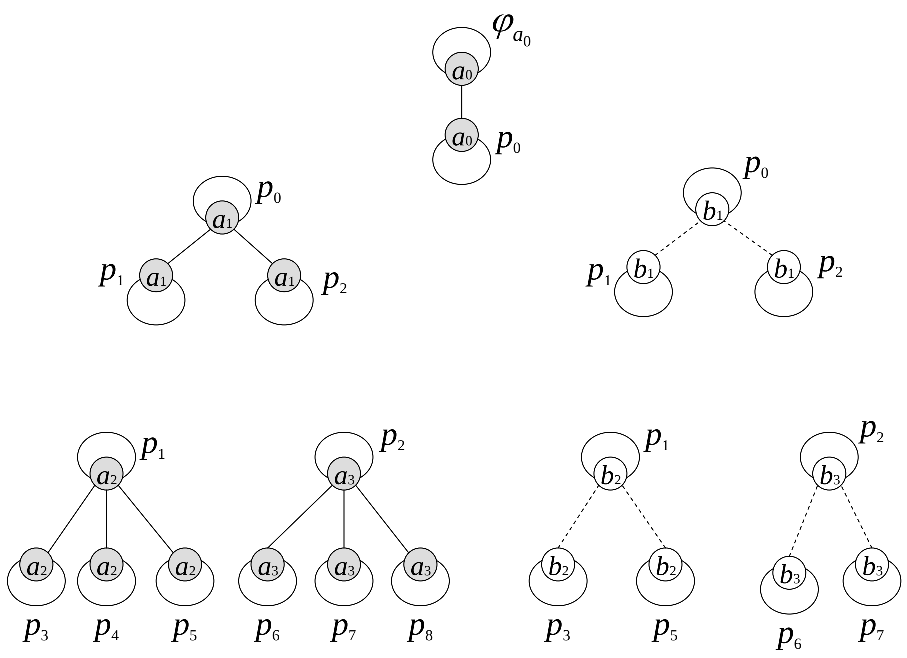


Figure 3 also illustrates a few other constructs of thematic networks. Given a thematic network δ and a position p in δ, we say that p is a *boundary position* in δ, if p answers to no positions, or no position answers to p in δ. δ is *closed* if every boundary position in δ is an empty position. Note that the thematic network in Figure 3 is closed whereas the thematic networks in Figures 1 and 2 are not closed. Building the terminology further, we call an empty position with a lead theme a *cap position*, and an empty position with a support theme a *base position*. Similarly, the theme of a cap position is a *cap theme*, and the theme of a base position is a *base theme*. For examples, the position φ_{a_0} in Figure 3 is a cap position, and positions such as φ_{b_6} and $\varphi_{a_{10}}$ in Figure 3 are base positions. Also in Figure 3, a_0 is a cap theme while b_6 and a_{10} are base themes.

Figure 4 Coordination Clauses of the Thematic Network in Figure 1



The thematic networks in Figures 1, 2 and 3 are also examples of *regular* thematic networks. Defining regular thematic networks, let δ be a thematic network. The set of all answer relationships in δ having the same theme is called a *coordination clause* of δ. Given a coordination clause, a position having a lead theme is called a *head* of the clause. A coordination clause is *regular* if it has a single head. δ is *regular* when every coordination clause in it is regular. Figure 4 shows coordination clauses of the thematic network in Figure 1. All of them are regular, and hence the thematic network in Figure 1 is regular. Similarly, it is straightforward to verify that the thematic networks in Figures 2 and 3 are also regular. In this study, we only discuss regular coordination clauses and regular thematic networks.

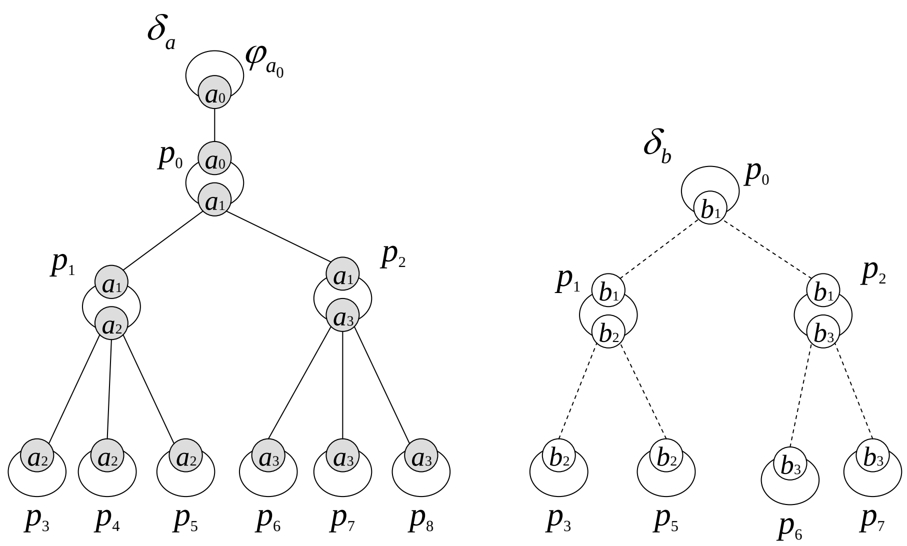
3. Overlay Aggregations of Thematic Networks

As stated earlier, thematic networks can be overlaid one on the other to construct increasingly more complex thematic networks. In this section, we give a formal articulation of overlay aggregations, based on a certain network union operation.

Definition 2. Let $\delta_i = (P_i, M_i, R_i, Z_i)$ be thematic networks for $i = 1, \cdots, n$, with $M_i \cap M_j = \varnothing$ for $i \neq j$. The *union* of thematic networks δ_i, written $\delta_1 \cup \delta_2 \cup \cdots \cup \delta_n$, is a tuple (P, M, R, Z) given by:

$$P = \bigcup_{i=1,\cdots,n} P_i,\ \ M = \bigcup_{i=1,\cdots,n} M_i,\ \ R = \bigcup_{i=1,\cdots,n} R_i,\ \text{and}\ Z = \bigcup_{i=1,\cdots,n} Z_i$$

Figure 5 Thematic Networks Whose Union is the Thematic Network in Figure 1

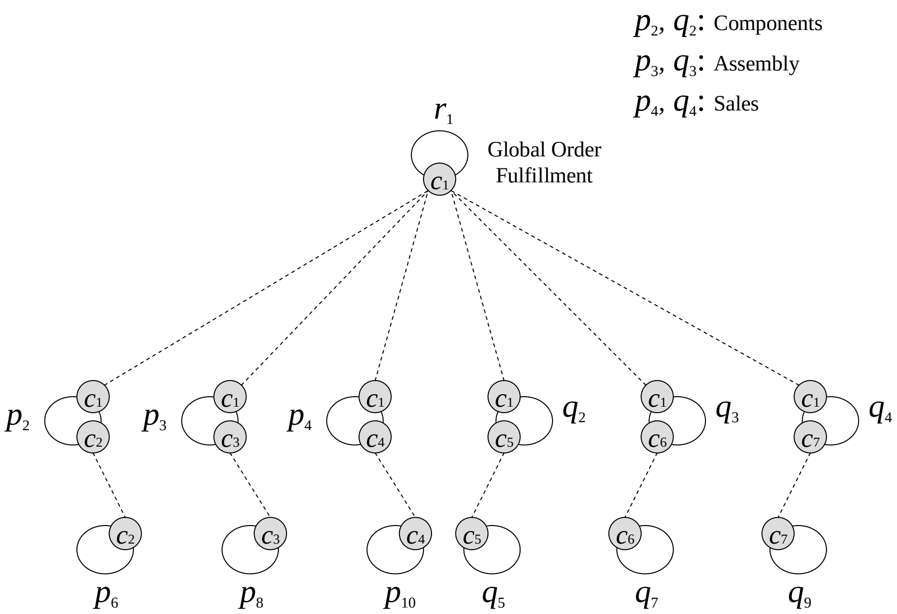


We say that a union of thematic networks with mutually disjoint sets of themes, as in the above definition, is a *thematically disjoint union* of thematic networks. It is straightforward to verify the following:

Proposition 1 (Network Union). A thematically disjoint union of thematic networks is a thematic network.

For an example, see the two thematic networks, δ_a and δ_b, in Figure 5. They are thematically disjoint: δ_a has themes along the business dimension whereas δ_b has themes along the geography dimension. The overlay aggregation of δ_a and δ_b, namely, $\delta_a \cup \delta_b$ is the thematic network in Figure 1. Similarly, the unit of Global Order Fulfillment (see Figure 6) can be overlaid, through the network union, on the base organization of geography consisting of Country A and Country B in Figure 2. Thus, these examples show that thematic networks formally represent the informal notion of overlay structures. Although popularly discussed in the literature, there was no rigorous understanding of what it means to overlay structures on other structures.

Figure 6 The Overlay Unit with the Strategic Theme of Global Order Fulfillment in Figure 2.



4. Positional and Thematic Views and their Duality

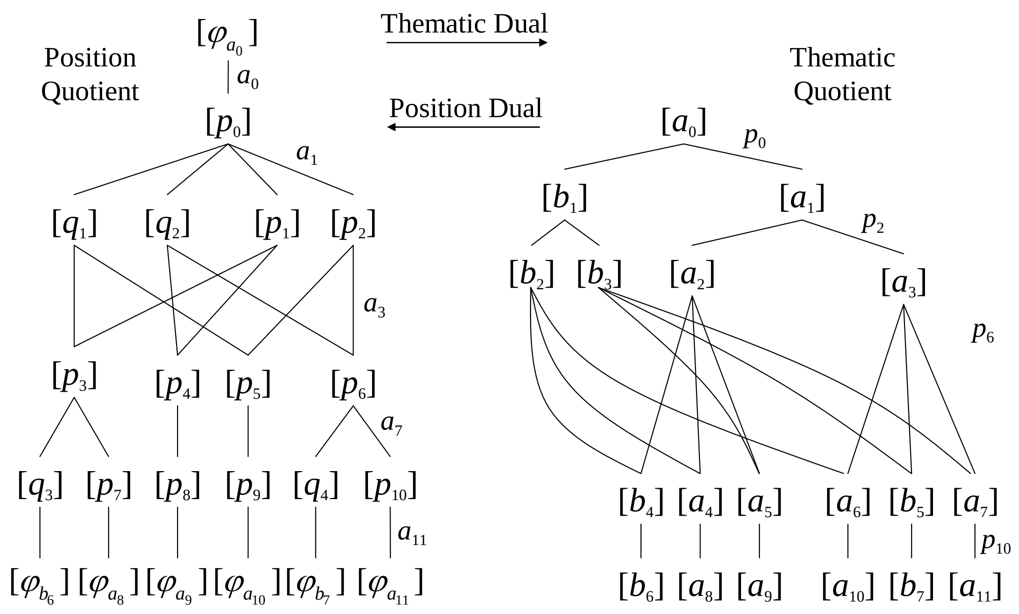
In the previous sections, thematic networks were viewed as collections of positions with task-oriented relationships among them. In addition to this positional view, thematic networks admit another view, namely the view that considers thematic networks as collections of themes with "attend to" relationships among them. Recall that "attend to" relationships were discussed among *tasks* in a previous section. They are now recaptured as relationships among *task themes*. In this section, we develop formal constructs to explicitly represent the positional and thematic views of thematic networks, and show that one view is the dual of the other.

We start with some preliminary concepts. When a thematic network has answer relationships $(p,a) \to (q,a)$, pairs such as (p,a) and (q,a) are called *fronts* of the thematic network. As a is a support theme of p, (p,a) is called a *support front*, and sometimes written $(p,a)^S$. Similarly, (q,a) is called a *lead front*, and sometimes written $(q,a)^L$. Every front in a thematic network is either a support front or a lead front, but not both at the same time, due to the thematic separation condition given in Definition 1. Now consider fronts $(p,a)^S$ and $(q,a)^L$. By definition, p answers to q through a. Recall that answer relationships are induced by task relationships. Namely, the underlying idea is that p is in charge of a task with a theme, say b, that attends to the task with theme a. So, p has front $(p,b)^L$. Given $(p,b)^L$ and $(p,a)^S$, we say b *attends to* a through p. We call "attend to" relationships among themes *attending* relationships.

We now develop formal constructs to separately focus on answer relationships and attending relationships. Given a thematic network δ, let X_δ be the set of all fronts in δ. We define an equivalence relation, $\approx_{\boldsymbol{p}}$, on X_δ. Namely, $x \approx_{\boldsymbol{p}} y$ if x and y has the same position. We write $[q]$ to denote the equivalence class of position q under the relation $\approx_{\boldsymbol{p}}$, *i.e.*, the set of all fronts having q as the position. The set of all such equivalence classes of X_δ is called the *quotient set* of X_δ under the relation $\approx_{\boldsymbol{p}}$, and written $X_\delta / \approx_{\boldsymbol{p}}$. Similarly, we define another equivalence relation, $\approx_{\boldsymbol{m}}$, on X_δ. Namely, $x \approx_{\boldsymbol{m}} y$ if x and y has the same theme. We write $[a]$ to denote the equivalence class of theme a under the relation $\approx_{\boldsymbol{m}}$, *i.e.*, the set of all fronts having a as the theme. We write $X_\delta / \approx_{\boldsymbol{m}}$ to denote the quotient set of X_δ under $\approx_{\boldsymbol{m}}$, i.e., the set of all equivalence classes of X_δ under $\approx_{\boldsymbol{m}}$.

Out of these two quotient sets, $X_\delta / \approx_{\boldsymbol{p}}$ and $X_\delta / \approx_{\boldsymbol{m}}$, we define two types of directed graphs, one capturing answer relationships and the other attending relationships. We first introduce some notations on directed graphs. A directed graph is given by a pair (V, E) where V is a set of *vertices* and E is a set of ordered pairs of distinct vertices called *directed edges*. A directed edge (x_1, x_2) is written $x_1 \to x_2$. Given a directed graph G, we write $V(G)$ to denote the set of all vertices of G, and $E(G)$ to denote the set of all directed edges of G.

Figure 7 Position and Thematic Quotients of the Thematic Network in Figure 3



We now define two quotient constructs to analyze answer and attending relationships separately.

Definition 3. Let δ be a thematic network, and X_δ be the set of all fronts of δ. The *position quotient* of δ, written $\boldsymbol{p}\mathcal{Q}(\delta)$, is a directed graph given by:

$$V(\boldsymbol{p}\mathcal{Q}(\delta)) = X_{\delta} / \approx_{\boldsymbol{p}}$$

$$E(\boldsymbol{p}\mathcal{Q}(\delta)) = \{[q] \xrightarrow{a} [p] \mid (q,a)^{S} \in [q], (p,a)^{L} \in [p]\}$$

Similarly, the *thematic quotient* of δ , written $\boldsymbol{m}\mathcal{Q}(\delta)$, is a directed graph given by:

$$V(\boldsymbol{m}\mathcal{Q}(\delta)) = X_{\delta} / \approx_{\boldsymbol{m}}$$

$$E(\boldsymbol{m}\mathcal{Q}(\delta)) = \{[b] \xrightarrow{p} [a] \mid (p,b)^{L} \in [\mathrm{b}],\ (p,a)^{S} \in [a]\}$$

For examples, see Figure 7. The directed graph on the left and the directed graph on the right in Figure 7 are, respectively, the position quotient and the thematic quotient of the thematic network in Figure 3. It is clear that the position quotient captures answer relationships of the thematic network while the thematic quotient represents attending relationships of the same thematic network.

Next, we define two dual constructors: the *thematic dual constructor*, denoted by $\Delta^{\boldsymbol{m}}$, which, given a position quotient, derives its thematic dual, and the *position dual constructor*, denoted by $\Delta^{\boldsymbol{p}}$, which, given a thematic quotient, constructs its position dual. We give some terminological conventions first. Given a cap position φ_a and a base position φ_b , we also call $[\varphi_a]$ and $[\varphi_b]$ a cap position and a base position, respectively. Similarly, given a cap theme a and a base theme b , we also call $[a]$ and $[b]$ a cap theme and a base theme, respectively.

Definition 4. Let δ be a thematic network. The *thematic dual* of its position quotient $\boldsymbol{p}\mathcal{Q}(\delta)$, written $\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta))$, is a directed graph given by:

$$V(\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta))) = \{[a] \mid [q] \xrightarrow{a} [p] \in E(\boldsymbol{p}\mathcal{Q}(\delta))\}$$

$$E(\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta))) = \{[a_1] \xrightarrow{p} [a_2] \mid [q_1] \xrightarrow{a_1} [p] \xrightarrow{a_2} [q_2] \text{ in } \boldsymbol{p}\mathcal{Q}(\delta)\}$$

Similarly, the *position dual* of $\boldsymbol{m}\mathcal{Q}(\delta)$, written $\Delta^{\boldsymbol{p}}(\boldsymbol{m}\mathcal{Q}(\delta))$, is a directed graph given by:

$V(\Delta^{p}(m\mathcal{Q}(\delta))) =$

$\{[p] \mid [b]\xrightarrow{p}[a] \in E(m\mathcal{Q}(\delta))\} \cup \{[\varphi_a] \mid [a]$ is a cap or a base theme in $m\mathcal{Q}(\delta)\}$

$E(\Delta^{p}(m\mathcal{Q}(\delta))) = \{[p_1]\xrightarrow{a}[p_2] \mid [b_1]\xrightarrow{p_1}[a]\xrightarrow{p_2}[b_2]$ in $m\mathcal{Q}(\delta)\} \cup$

$\{[p]\xrightarrow{a}[\varphi_a] \mid [b]\xrightarrow{p}[a] \in E(m\mathcal{Q}(\delta))$ and $[a]$ is a cap theme in $m\mathcal{Q}(\delta)\} \cup$

$\{[\varphi_b]\xrightarrow{b}[p] \mid [b]\xrightarrow{p}[a] \in E(m\mathcal{Q}(\delta))$ and $[b]$ is a base theme in $m\mathcal{Q}(\delta)\}$

For examples of position and thematic duals, see Figure 7. The position quotient is the position dual of the thematic quotient, while the thematic quotient is the thematic dual of the position quotient. This duality relationship between position quotients and thematic quotients holds in general.

Proposition 2 (Quotient Duality). Let δ be a closed thematic network.

(1) $\Delta^{m}(p\mathcal{Q}(\delta)) = m\mathcal{Q}(\delta)$

(2) $\Delta^{p}(m\mathcal{Q}(\delta)) = p\mathcal{Q}(\delta)$

5. Reporting Hierarchy

While thematic networks can be massively connected, it is still essential for the firm to retain a hierarchical reporting structure. Given a thematic network, a reporting structure in it should be *complete* in the sense that every position in the network appears in the structure. A reporting structure should also respect the unity of command, i.e., every position has exactly a single position to report to, except the top position.

We first characterize a general class of thematic networks for which one can always find complete reporting hierarchies. We first introduce some basic concepts of directed graphs (Bang-Jensen and Gutin 2001). When a directed graph G has a chain of directed edges of the form $(x_1, x_2), (x_2, x_3), \cdots, (x_{n-1}, x_n)$, we say that x_n is *reachable* from x_1 in G, and write $x_1 \leq_G x_n$, or simply $x_1 \leq x_n$ when G is clear from the context. For the reason of formal convenience, we assume x is reachable from x (and hence $x \leq x$). Given distinct x_i and x_j, when they are mutually reachable from each other, a chain from x_i to itself through x_j is a *cyclic chain*. G is *cyclic* if G has one or more cyclic chains. Otherwise, G is *acyclic*. We say G is *rooted* if there exists $x \in V(G)$ such that for every $y \in V(G)$, $y \leq_G x$. x is called a *root* of G. Note that a rooted directed graph has a unique root when it is acyclic, and that the unique root has no parents. A rooted, acyclic directed graph is a *tree* if every vertex other than its root has exactly a single parent.

Let δ be a thematic network. $\boldsymbol{p}\mathcal{Q}(\delta)$ is *properly rooted* if it has a cap position $[\varphi_a]$ which is reachable from every position other than other cap positions. $[\varphi_a]$ is called a *proper root* of $\boldsymbol{p}\mathcal{Q}(\delta)$. Similarly, $\boldsymbol{m}\mathcal{Q}(\delta)$ is *properly rooted* if it has a cap theme $[a]$ which is reachable from every theme other than other cap themes. $[a]$ is called a *proper root* of $\boldsymbol{m}\mathcal{Q}(\delta)$.

Proposition 3 (Dual-Preservation Properties). Let δ be a thematic network.

(1) $\boldsymbol{p}\mathcal{Q}(\delta)$ is acyclic if and only if $\boldsymbol{m}\mathcal{Q}(\delta)$ is acyclic.

(2) Assume δ is closed. Then $\boldsymbol{p}\mathcal{Q}(\delta)$ is properly rooted if and only if $\boldsymbol{m}\mathcal{Q}(\delta)$ is properly rooted.

In light of Proposition 3, we say a thematic network is *acyclic* if its position quotient is acyclic. Similarly, we say that a thematic network is *properly rooted* if its position quotient is properly rooted. In this paper, we focus on the class of acyclic thematic networks and properties specific to this class. This choice naturally follows from the idea underlying the notion of answer relationships. Recall that we say p answers to q when a task that p is in charge of attends to a task that q is in charge of. When a task, say A, attends to another task, say B, the sense is that task B is at a *higher-level* than task A through containment or subsumption relationships between the two tasks. This fundamental asymmetry disallows cyclic attending relationships among tasks. Since answer relationships are induced by attending relationships, acyclic answer relationships naturally follow.

We now formalize a procedure to derive reporting structures.

Definition 5. Let δ be a properly rooted thematic network, and $[\varphi_a]$ a proper root of $\boldsymbol{p}\mathcal{Q}(\delta)$. A *position hierarchy* of $\boldsymbol{p}\mathcal{Q}(\delta)$ rooted at $[\varphi_a]$ is a position quotient obtained from $\boldsymbol{p}\mathcal{Q}(\delta)$ by the following procedure:

Step 1: Remove every cap position other than $[\varphi_a]$ and its incoming edges: *i.e.*, for every clause of the form $\{(q_1,b) \to (\varphi_b,b),(q_2,b) \to (\varphi_b,b),\cdots,(q_n,b) \to (\varphi_b,b)\}$, remove $(\varphi_b,b)^L$ from $[\varphi_b]$, and $(q_i,b)^S$ from $[q_i]$ for each $1 \le i \le n$.

Step 2: For every non-empty position $[q]$ having two or more outgoing edges after Step 1, remove all but one of those edges and add new positions of the form $[\varphi_{a_i}]$ where a_i is the label of a removed edge: *i.e.*, for each collection of edges $\{[q] \xrightarrow{a_i} [p_i]\}_{1 \le i \le n}$, with $n \ge 2$, select *any* integer k between 1 and n, and remove $(q,a_i)^S$ from $[q]$ for all $i \ne k$, and add $[\varphi_{a_i}] = \{(\varphi_{a_i},a_i)^S\}$ for all $i \ne k$ as new vertices.

For an example, see Figure 8. The directed graph on the left is a position hierarchy of the position quotient in Figure 7. Similarly, we also define a procedure to derive hierarchical thematic structures. Given the duality between the positional and thematic views established earlier, out aim is to derive a parallel duality directly between position hierarchies and thematic hierarchies. This is of course motivated by the desire to identify position hierarchies, i.e., reporting structures, through the thematic view.

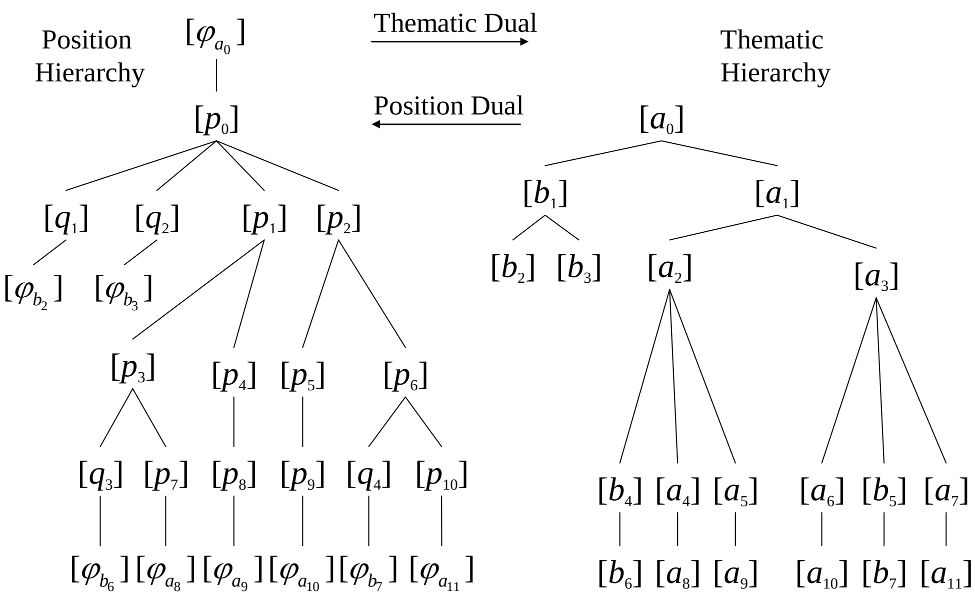
Definition 6. Let δ be a properly rooted thematic network, and $[a]$ be a proper root of $\boldsymbol{m\mathcal{Q}}(\delta)$. A *thematic hierarchy* of $\boldsymbol{m\mathcal{Q}}(\delta)$ rooted at $[a]$ is a thematic quotient obtained from $\boldsymbol{m\mathcal{Q}}(\delta)$ by the following procedure:

Step 1: Remove every cap theme other than $[a]$ and its incoming edges: *i.e.*, if $[b]$ is a cap theme other than $[a]$, remove the vertex $[b]$ from the set of vertices $X_\delta / \approx_{\boldsymbol{m}}$ (and consequently all incoming edges to $[b]$).

Step 2: For every vertex $[c]$ having two or more outgoing edges after Step 1, remove all but one of those edges, and make each parent of $[c]$ with a removed edge an base theme: *i.e.*, for each collection of edges $\{[x] \xrightarrow{p} [a_i]\}_{1 \le i \le n}$ with $n \ge 2$ and $[x]$ possibly varying over two or more themes , select any integer k between 1 and n, and remove $(p, a_i)^S$ from $[a_i]$ for each $i \neq k$, and make $[a_i]$ a base theme by adding a base front $(\varphi_{a_i}, a_i)^S$ to it for each $i \neq k$.

For an example, see Figure 8. The directed graph on the right is a thematic hierarchy of the thematic quotient in Figure 7.

Figure 8 A Position Hierarchy (left) and a Thematic Hierarchy (right) of the Position Quotient and the Thematic Quotient in Figure 6, respectively



In these examples, both directed graphs actually exhibit tree structure. The next proposition shows that this observation is in fact the case in general.

Proposition 4 (Quotient Hierarchies). Let δ an acyclic, closed and properly rooted thematic network. Let K be a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$, and H a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$.

(1) K is a tree, and for every non-empty position $[p]$ in $\boldsymbol{p}\mathcal{Q}(\delta)$, $[p] \in V(K)$.

(2) H is a tree, and for every theme $[b]$ in $\boldsymbol{m}\mathcal{Q}(\delta)$ other than cap themes, $[b] \in V(H)$.

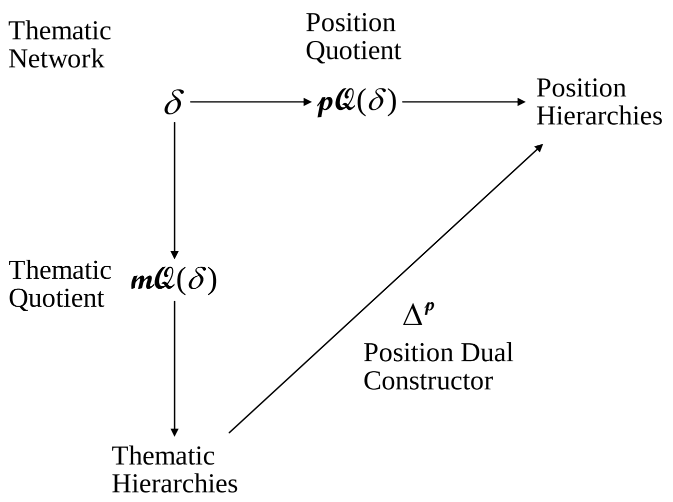
Finally, our key result is the duality between position hierarchies and thematic hierarchies.

Proposition 5 (Hierarchy Duality). Let δ an acyclic, closed and properly rooted thematic network.

(1) The thematic dual of a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$ is a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$.

(2) The position dual of a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$ is a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$.

Figure 9 Tow Paths for Deriving Reporting Hierarchies



For an example, see Figure 8. One hierarchy is the dual of the other.

Corollary. Let δ an acyclic, closed and properly rooted thematic network. There is a bijection between the collection of position hierarchies of $\boldsymbol{p}\mathcal{Q}(\delta)$ and the collection of thematic hierarchies of $\boldsymbol{m}\mathcal{Q}(\delta)$.

Figure 9 summarizes the construction of reporting hierarchies. The point is that given a properly rooted thematic network, its reporting hierarchies can be derived either directly from its position quotient or indirectly through its thematic quotient.

6. Discussion

The fundamental observation in this paper is the structural nature of interacting strategic themes, namely, the idea that due to the "structural effects", the whole competitive value of interacting strategic themes is not reducible to a collection of competitive values of individual strategic themes (Porter 1996). When interacting strategic themes are mapped organizationally, their network representation often has "structural manifestation" as in various forms of overlay structure. Given this structural nature of interacting strategic themes both in their generation of competitive values and in their organizational manifestation, we use the term *structural advantage* to refer to competitive advantage that derives from effective management of interacting strategic themes for superior fit. The notion of structural advantage is useful in summarizing and interpreting some of the key concepts and main results of this paper.

We first discuss overlay structures. The mirror-image coordination structure in Figure 1 shows a simple case. The business theme and the geography theme in this case are addressed by two distinct thematic networks, each focusing on one of the themes (Figure 5). One of the key concerns of the business theme is typically the scale economies, which is addressed through various means such as standardization in product design and worldwide marketing. On the other hand, a main concern of the geography theme is usually adaptation to local markets. Thus, the business and geography themes are likely to contain conflicting concerns such as standardization for the economies of scale and variation for local adaptation. In the mirror-image coordination in Figure 1, these conflicting concerns are to be managed by overlaying the geography structure (δ_b in Figure 5) upon the business structure (δ_a in Figure 5). This example illustrates two points. One is that when we say "interacting strategic themes", they are not always "complementary" (Milgrom and Roberts 1995) or "mutually reinforcing" (Porter 1996), but they might represent "contradictory strategic agendas" (Smith and Tushman 2005). Thus, the notion of fit needs to be broadly understood to include all forms of interaction among strategic themes. The second point is that the overlay of the business and geography thematic networks is a structural means of managing the interaction of the two corresponding strategic themes. The mirror-image coordination is a simple case of structural coordination, but in general, overlay structures are a powerful, structural means of managing multiple strategic themes interacting either positively or negatively to create fit among them for structural advantage.

Through their union operation, thematic networks formally capture overlay structures of arbitrary complexity. Earlier we stated that thematic networks are an extension of multigraphs. Mathematically, however, multigraphs are sufficient for representing overlay structures. As an extension of directed graphs, a multigraph comes with two or more sets of relations on the set of its vertices. Referring to the notation introduced earlier, a multigraph is given by $(V, \{E_1, E_2, \cdots, E_k\})$ where V is a set of vertices and each E_i is a relation on V. Given a thematic network $\delta = (P, M, R, Z)$, we can derive a multigraph $(P, \{\overline{a}_i\}_{a_i \in M})$ by viewing each theme as a relation on the set of positions (denoted by $\overline{a}_i$). Such multigraphs typically come with a large set of relations with each relation being rather small, but they are sufficient to represent overlay structures.

Mathematically, then, what distinguishes thematic networks from multigraphs is the fact that thematic networks come with an additional structure, namely a partial order on the set of relations. As given above, the set of relations in a thematic network is the set of themes $\{\overline{a}_i\}_{a_i \in M}$ viewed as relations on the set of positions of the thematic network. Consider, for instance, the thematic quotient in Figure 7, and note that the quotient captures a partial order on the set of themes. In general, attending relationships among themes in a thematic quotient represent a partial order on themes (when they are transitively closed). It should be noted here that the sense of “order” among themes is intrinsically related to the way competitive advantage is formed. Consider tasks of a firm and competitive values they generate. These values must then be integrated to derive increasingly more comprehensive forms of competitive value, towards the final shape of the firm’s competitive advantage. A partial order on themes of tasks naturally captures this stratified formation of competitive advantage. Recall that answer relationships are induced by attending relationships. Thus, conceptually, answer relationships are not a “relaxed” version of reporting relationships, but they too reflect the stratified nature of how competitive advantage is structured.

As made explicit through position and thematic quotients, thematic networks embrace dual structures, one determined by positions and their answer relationships and the other specified by themes and their attending relationships. This duality of thematic networks is a source of their expressiveness. As an example, let us define a class of positions using thematic constructs. Given a theme a in a thematic network, its *thematic closure* is the set of all themes that a is reachable from in the thematic quotient of the thematic network (recall a thematic quotient is a directed graph, and reachability is defined on directed graphs). For instance, the thematic closure of theme b_2 in the thematic quotient in Figure 7 is the set $\{b_2, b_4, b_6, a_4, a_6, a_8, a_{10}\}$. Given a position p in a thematic network, its thematic closure is the set of themes of p together with the thematic closure of its lead theme for every lead theme of p. For instance, the thematic closure of position q_1 in the thematic network in Figure 3 is the set $\{b_1, b_2, b_4, b_6, a_4, a_6, a_8, a_{10}\}$. A position is called a *thematic integrator* when its thematic closure contains two or more themes which must be managed for mutual reinforcement, conflict resolution, or any other reasons of effective integration. Position q_1 in Figure 3 is likely to be a thematic integrator as its thematic closure contains themes related to Country A and themes related to Business Unit 1. Matrix managers are another good example of thematic integrators. Thus, thematic integrators serve as critical linking agents for interacting strategic themes. Particularly when these themes contain conflicting elements and exhibit tensions among them, thematic integrators must learn to "embrace rather than avoid or deny theses tensions" (Smith and Tushman 2005, p. 527). Once they develop a proper "frame of mind" (Bartlett and Ghoshal 1990) for embracing multiple, possibly conflicting themes, thematic integrators may function as key contributors in building structural advantage through effective management of strategically related but structurally distant organizational layers.

Going back to the duality of thematic networks, thematic integrators are just one example of how analytical constructs can be developed by exploiting the duality. The most notable example in this regard is probably the construction of reporting hierarchies through thematic structures (Proposition 5). This makes an intuitive sense once one recalls that thematic structures captures how themes are related to higher-level themes for delivering increasingly more comprehensive competitive values. Any reporting structure should respect the stratified formation structure of competitive advantage. Similarly, the original duality results between position and thematic quotients (Proposition 2) are consistent with the conceptually dual nature of answer and attending relationships, namely, "a position answering to another position through a theme" and "a theme attending to another theme through a position".

There seems to be, however, a deeper interpretation of the duality in thematic networks. This interpretation is based on Giddens' structuration theory. The theory was developed in a broader context of sociological studies, but has been applied to organizational settings by various scholars (DeSanctis and Pool 1994, Orlikowski 2000, Orlikowski 2002, Perlow et al. 2004). Giddens' theory articulates the dual nature of "structure" and "activities of human agents". According to the theory, "structure" is both medium that constrains and enables "activities", and at the same time outcome of "activities"(Giddens 1984, p.25). Furthermore, "structure" is not external to individuals, but "structure only exists in and through the activities of human agents" (Giddens 1989, p.256).

Accepting Giddens' "duality of structure" as an interpretation that underlies the duality results of the positional view and the thematic view (Proposition 2), the recursive dynamics between "structure" and "activities" can be recaptured in the setting of thematic networks. A resulting perspective is then the recursive dynamics between network structure in the positional view and theme-driven activities in the thematic view. More compactly, the perspective states that network structure exists "in and through" theme-driven activities. The duality results on the positional and thematic views (Proposition 2) are consistent with this perspective. After all, the duality implies that one view is implicitly present in the other view.

7. Conclusion

Thematic networks represent only a formal core for organizational domains. Other organizational elements such as incentive systems, accountability, information sharing, trust and shared value complement the formal core to form more comprehensive organizational domains for analysis of strategic fit. Thematic networks as a formal core, however, offer three key organizational perspectives for the study of strategic fit.

One is the extended notion of overlay structures. As stated earlier, overlay structures are extensively discussed in the literature. But due to the lack of sufficiently expressive and rigorous languages, the type of overlay structures possible to represent and analyze was rather limited. As the examples in Figures 1, 2 and 3 illustrate, we can begin to collect a wide range of new overlay structures that coordinate and integrate interacting themes for strategic fit.

The second perspective is about thematic integrators. Thematic integrators are similar to "gatekeepers" (Tushman and Katz 1980) and "boundary spanners" (Hansen 2002, Perrone et al. 2003) in the sense that the scope of their activities or concerns cuts across structural boundaries. But thematic integrators have an additional role of integratively coping with multiple, possibly conflicting themes for superior fit. As stated earlier, thematic networks can represent overlay structures of arbitrary complexity. Also, the notion of structure in thematic networks is much finer than the conventional organization structure. Thus there is a possibility of finding new types of thematic integrators through new forms of overlay structures.

The third perspective is about the dynamic nature of fit-creating activities. While thematic integrators typically operate within predefined structural contexts, firms occasionally create new structural contexts for further strategic fit. One reading of the duality results of the positional and thematic views (Proposition 2) is that network-structure is implicitly present in theme-driven activities. This in turn implies that if new activities are initiated new structures might also be created. In fact, this was well observed in a recent field work by the author and his colleagues. In a series of interviews of 15 managers at one of the largest retail chains in Japan, several cases of informal network formation were recognized. Interestingly, in every case, a group of people, often from various parts of the organization, first identified and initiated a new task which cuts across structural boundaries. Changing the surrounding network structure or creating a new structure was not their initial agenda. But, a new structure emerged as a consequence of engaging in a new boundary-spanning task. Although such new structures were by-products of collaborative efforts on new tasks, sometimes, some members of a group, particularly the leader, were well aware of the organizational value of such structural by-products. Thus, the duality of thematic networks captures the structure-creating dynamics of organizations for superior strategic fit.

References

Bang-Jensen, J., G. Gutin. 2001. *Digraphs: Theory, Algorithms and Applications*. Springer, London.

Bartlett, C., S. Ghoshal. 1990. Matrix management: Not a structure, a frame of mind. *Harvard Business Review*, 68(4) 138-145.

Basu, A., R. Blanning. 2000. A formal approach to workflow analysis. *Information Systems Research.* 11(1) 17-36.

Brown, S., K. Eisenhardt. 1997. The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly*. 42 1-34.

Davey, B., H. Priestley. 2002. *Introduction to Lattices and Order*. Cambridge University Press, Cambridge, UK.

Davis, S., P. Lawrence. 1977. *Matrix*. Addison-Wesley Publishing, Reading, MA.

Desanctis, G., M. Poole. 1994. Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory. *Organization Science* 5(2) 121-147.

Eisenhardt, K., J. Martin. 2000. Dynamic capabilities: What are they? *Strategic Management Journal.* 21 1105-1121.

Eppinger, S., D. Whitney, R. Smith, D. Gebala. 1994. A model-based method for organizing tasks in product development. *Research in Engineering Design*. **6** 1-13.

Fenton, E., A. Pettigrew. 2000. The Role of Social Mechanisms in an Emerging Network: The Case of the Pharmaceutical Network in Coopers & Lybrand Europe. A. Pettigrew, E. Fenton, eds. *The Innovating Organization*, Sage Publications, London, 82-116.

Galbraith, J. 1973. *Designing Complex Organizations*. Addison-Wesley Publishing, Reading, MA.

Galbraith, J. 2000. *Designing the Global Corporation*. Jossey-Bass, San Francisco, CA.

Giddens, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration*. University of California Press, Berkeley.

Giddens, A. 1989. A reply to my critics. D. Held, J.B. Thompson, eds. *Social Theory of Modern Societies: Anthony Giddens and his Critics*. Cambridge University Press, Cambridge, UK, 249-301.

Goold, M., A. Campbell. 2002. *Designing Effective Organizations: How to Create Structured Networks*. Jossey-Bass, San Francisco, CA.

Gunter, C., D. Scott. 1990. Semantic domains. J. van Leeuwen, editor, *Handbook of Theoretical Computer Science, Volume B, Formal Models and Semantics*. The MIT Press, Cambridge, MA, 633-674.

Hansen, M. 2002. Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organization Science*. 13(3) 232-248.

Kellogg, K., W. Orlikowski, J. Yates. 2006. Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations. *Organization Science* 17(1) 22-44.

Levitt, R., J. Thomsen, T. Christiansen, J. Kunz, Y. Jin, C. Nass. 1999. Simulating project work processes and organizations: Toward a micro-contingency theory of organization design. *Management Science*. 45(11) 1479-1495.

Malone, T., K. Crowston, J. Lee, B. Pentland, C. Dellarocas, G. Wyner, J. Quimby, C. Osborn, A. Bernstrein, G. Herman, M. Klein, E. O'Donnell. 1999. Tools for reinventing organizations: Toward a handbook of organizational processes. *Management Science*. 45(3) 425-443.

Milgrom, P., J. Roberts. 1990. The economics of modern manufacturing: Technology, strategy, and organization. *American Economic Review*. 80 511-528.

Milgrom, P., J. Roberts. 1995. Complementarities and fit: Strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*. 19 179-208.

Mintzberg, H. 1979. *The Structuring of Organizations*. Prentice-Hall, Inc., Englewood Cliffs.

Orlikowski, W. 2000. Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations, *Organization Science* 11(4) 404-428.

Orlikowski, W. 2002. Knowing in Practice: Enacting a Collective Capability in Distributed Organizing, *Organization Science* 13(3) 249-273.

Pattison, P. 1993. *Algebraic Models for Social Networks.* Cambridge University Press, Cambridge, UK.

Perlow, L., J. Gittell, N. Katz. 2004. Contextualizing patterns of work group interaction: Toward a nested theory of structuration. *Organization Science*. 15(5) 520-536.

Perrone, V., A. Zaheer, B. McEvily. 2003. Free to be trusted? Organizational constraints on trust in boundary spanners, *Organization Science* 14(4) 422-439.

Porter, M. 1996. What is Strategy? *Harvard Business Review*. 74(6) 61-78.

Porter, M., N. Siggelkow. 2008. Contextuality within activity systems and sustainability of competitive advantage. *Academy of Management Perspectives.* 22(2) 34-56.

Rindova, V., S. Kotha. 2001. Continuous “morphing”: Competing through dynamics capabilities, form and function. *Academy of Management Journal*. 44(6) 1263-1280.

Rivkin, J. 2000. Imitation of complex strategies. *Management Science* 46(6) 824-844.

Rivkin, J., N. Siggelkow. 2007. Patterned interactions in complex systems: Implications for exploration. *Management Science* 53(7) 1068-1085.

Siggelkow, N. 2002. Misperceiving interactions among complements and substitutes: Organizational consequences. *Management Science.* 48(7) 900-916.

Smith, W., M. Tushman. 2005. Managing strategic contradictions: A top management model for managing innovation streams. *Organization Science*. 16(5) 522-536.

Stoltenberg-Hansen, V., I. Lindstrom, E. Griffor. 1994. *Mathematical Theory of Domains*. Cambridge University Press, Cambridge, UK.

Teece, D., G. Pisano, A. Shuen. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal*. 18(7) 509-533.

Tushman, M., R. Katz. 1980. External communication and project performance: An investigation into the role of gatekeepers. *Management Science* 26(11) 1071-1085.

Volberda, H. 1996. Toward the flexible form: How to remain vital in hypercompetitive environments. *Organization Science*. 7(4) 359-374.

Wasserman, S., K. Faust. 1994. *Social Network Analysis: Methods and Applications*. Cambridge University Press, Cambridge, UK

Appendix

Proofs of Statements

Proposition 1 (Network Union). A thematically disjoint union of thematic networks is a thematic network.

Proof. We first introduce a notation. Given a thematic network with R as its set of answer relationships, define the following sets:

- $R^S = \{x \mid x \to y \in R\}$
- $R^L = \{y \mid x \to y \in R\}$

Note that $R^S \cap R^L = \varnothing$ if and only if for each position of the thematic network the set of support themes of the position is disjoint from the set of lead themes of the position. Let $\delta_i = (P_i, M_i, R_i, Z_i)$ be thematic networks for $i = 1, \cdots, n$, with $M_i \cap M_j = \varnothing$ for $i \neq j$, and $\delta = (P, M, R, Z)$ their union. It suffices to show $R^S \cap R^L = \varnothing$. Suppose $R^S \cap R^L \neq \varnothing$ and let $(p, a) \in R^S \cap R^L$. Then $a \in M_k$ and $a \notin \bigcup_{i \neq k} M_i$.

Note that $R^S = \bigcup_{1 \le i \le n} R_i^S$. Thus, $(p, a) \notin \bigcup_{i \neq k} R_i^S$ and $(p, a) \in R_k^S$. Similarly, $R^L = \bigcup_{1 \le i \le n} R_i^L$, and hence $(p, a) \notin \bigcup_{i \neq k} R_i^L$ and $(p, a) \in R_k^L$. We obtain a contradiction $(p, a) \in R_k^S \cap R_k^L$.

∎

Proposition 2 (Quotient Duality). Let δ be a closed thematic network.

(1) $\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta)) = \boldsymbol{m}\mathcal{Q}(\delta)$

(2) $\Delta^{\boldsymbol{p}}(\boldsymbol{m}\mathcal{Q}(\delta)) = \boldsymbol{p}\mathcal{Q}(\delta)$

Proof for (1). Let $\delta = (P, M, R, Z)$.

$[a] \in V(\boldsymbol{m}\mathcal{O}(\delta))$ if and only if

$[a] \in X_\delta / \approx_{\boldsymbol{m}}$ if and only if

For some $q, p \in P$, $(q,a) \to (p,a) \in R$ if and only if

$[q] \xrightarrow{a} [p] \in E(\boldsymbol{p}\mathcal{Q}(\delta))$ if and only if

$[a] \in V(\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta)))$

$[a_1] \xrightarrow{p} [a_2] \in E(\boldsymbol{m}\mathcal{O}(\delta))$ if and only if

$(p,a_1)^L \in [a_1]$ and $(p,a_2)^S \in [a_2]$ if and only if

For some $q_1, q_2 \in P$, $(q_1,a_1) \to (p,a_1), (p,a_2) \to (q_2,a_2) \in R$ as δ is closed if and only if

$[q_1] \xrightarrow{a_1} [p] \xrightarrow{a_2} [q_2]$ in $\boldsymbol{p}\mathcal{Q}(\delta)$ if and only if

$[a_1] \xrightarrow{p} [a_2] \in E(\Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta)))$.

□

Proof for (2). Let $\delta = (P, M, R, Z)$. We first show $V(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\mathcal{Q}(\delta))) = V(\boldsymbol{p}\mathcal{Q}(\delta))$.

For an empty position φ_a,

$[\varphi_a] \in V(\boldsymbol{p}\mathcal{Q}(\delta))$ if and only if

$[\varphi_a]$ contains a front (φ_a, a) if and only if

$[a]$ contains a front (φ_a, a) if and only if

$[a]$ is a cap or base in $\boldsymbol{m}\mathcal{O}(\delta)$ if and only if

$[\varphi_a] \in V(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\mathcal{Q}(\delta)))$.

For a non-empty position p,

$[p] \in V(\boldsymbol{p}\mathcal{Q}(\delta))$ if and only if

p has some support theme a and some lead theme b as δ is closed if and only if

$[b] \xrightarrow{p} [a] \in E(\boldsymbol{m}\boldsymbol{\mathcal{O}}(\delta))$ if and only if

$[p] \in V(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)))$.

Now we show $E(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta))) = E(\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta))$.

For $[q] \xrightarrow{a} [\varphi_a]$ where q is a non-empty position,

$[q] \xrightarrow{a} [\varphi_a] \in E(\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta))$ if and only if

$[b] \xrightarrow{q} [a] \in E(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta))$ for some $[b]$ where $[a]$ is a cap in $\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)$ if and only if

$[q] \xrightarrow{a} [\varphi_a] \in E(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)))$.

For $[\varphi_b] \xrightarrow{b} [p]$ where p is a non-empty position,

$[\varphi_b] \xrightarrow{b} [p] \in E(\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta))$ if and only if

$[b] \xrightarrow{p} [a] \in E(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta))$ for some $[a]$ where $[b]$ is a base in $\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)$ if and only if

$[\varphi_b] \xrightarrow{b} [p] \in E(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)))$.

For $[q] \xrightarrow{b} [p]$ where p and q are both non-empty positions,

$[q] \xrightarrow{b} [p] \in E(\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta))$ if and only if

$[c] \xrightarrow{q} [b] \xrightarrow{p} [a]$ in $\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)$ for some $[a]$ and $[c]$ as δ is closed if and only if

$[q] \xrightarrow{b} [p] \in E(\Delta^{\boldsymbol{p}}(\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)))$.

$\square$

Proposition 3 (Dual-Preservation Properties). Let δ be a thematic network.

(1) $\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta)$ is acyclic if and only if $\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)$ is acyclic.

(2) Assume δ is closed. Then $\boldsymbol{p}\boldsymbol{\mathcal{Q}}(\delta)$ is properly rooted if and only if $\boldsymbol{m}\boldsymbol{\mathcal{Q}}(\delta)$ is properly rooted.

Proof for (1). We first introduce a definition as an aid for proof. We say that a thematic network is *cyclic* if it has a chain of answer relationships of the following form:

$$(p_0,a_0)\rightarrow(p_1,a_0),(p_1,a_1)\rightarrow(p_2,a_1),\cdots,(p_{n-1},a_{n-1})\rightarrow(p_n,a_{n-1}),(p_n,a_n)\rightarrow(p_0,a_n)$$

Note that $\boldsymbol{p}\mathcal{Q}(\delta)$ is cyclic if and only if δ is cyclic. Note also that $\boldsymbol{m}\mathcal{Q}(\delta)$ is cyclic if and only if δ is cyclic.

$\square$

Proof for (2). Similar to the proof above, we first introduce a definition. We say that a thematic network is *properly rooted* if it has an empty position φ_a such that for every non-empty position q_0, it has a chain of answer relationships of the following form:

$$(q_0,b_1)\rightarrow(q_1,b_1),(q_1,b_2)\rightarrow(q_2,b_2),\cdots,(q_{n-1},b_n)\rightarrow(q_n,b_n),(q_n,a)\rightarrow(\varphi_a,a)$$

Note that $\boldsymbol{p}\mathcal{Q}(\delta)$ is properly rooted if and only if δ is properly rooted. It remains to show that δ is properly rooted if and only if $\boldsymbol{m}\mathcal{Q}(\delta)$ is properly rooted. Suppose that δ is properly rooted at φ_a. We show that $\boldsymbol{m}\mathcal{Q}(\delta)$ is properly rooted at $[a]$. Let $[b_0]$ be a non-cap in $\boldsymbol{m}\mathcal{Q}(\delta)$. Then b_0 is a lead theme of some non-empty position. Call it q_0. As q_0 is non-empty, by the supposition, δ has a chain of answer relationships of the form specified above. Thus $[a]$ is reachable from $[b_1]$. But as b_0 is a lead theme of q_0, $[b_0]\xrightarrow{q_0}[b_1]$ in $\boldsymbol{m}\mathcal{Q}(\delta)$. Thus, $[a]$ is reachable from $[b_0]$. Now suppose $\boldsymbol{m}\mathcal{Q}(\delta)$ is properly rooted, and let $[a]$ be its proper root. Since $[a]$ is a cap in $\boldsymbol{m}\mathcal{Q}(\delta)$, it contains a cap front $(\varphi_a,a)^L$. We show that δ is properly rooted at φ_a. Let q_0 be a non-empty position in δ. Since δ is closed, q_0 has a lead theme. Call it b_0. Since $[b_0]$ is not a cap in $\boldsymbol{m}\mathcal{Q}(\delta)$, $[a]$ is reachable from $[b_0]$, and $\boldsymbol{m}\mathcal{Q}(\delta)$ has a chain of the following form:

$$[b_0]\xrightarrow{q_0}[b_1]\xrightarrow{q_1}\cdots\xrightarrow{q_{n-1}}[b_n]\xrightarrow{q_n}[a]$$

Since $[a]$ contains $(\varphi_a,a)^L$, we obtain a chain of answer relationships of the form specified above. Thus, δ is properly rooted. We have shown that $\boldsymbol{m}\mathcal{Q}(\delta)$ is properly rooted if and only if δ is properly rooted.

$\square$

Proposition 4 (Quotient Hierarchies). Let δ an acyclic, closed and properly rooted thematic network. Let K be a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$ rooted at $[\varphi_a]$, and H a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$ rooted at $[a]$.

(1) K is a tree, and for every non-empty position $[p]$ in $\boldsymbol{p}\mathcal{Q}(\delta)$, $[p] \in V(K)$.

(2) H is a tree, and for every theme $[b]$ in $\boldsymbol{m}\mathcal{Q}(\delta)$ other than cap themes, $[b] \in V(H)$.

Proof for (1). We first show K is a tree. Since $\boldsymbol{p}\mathcal{Q}(\delta)$ is acyclic, by the construction of K, K is acyclic. Note that $[\varphi_a] \in V(K)$. As $[\varphi_a]$ is a cap, it has no parents. It suffices to show that every vertex of K other than $[\varphi_a]$ has exactly a single parent: as K is acyclic, $[\varphi_a]$ would then be reachable from every vertex of K. Let $[q]$ be a vertex of K other than $[\varphi_a]$. Since $[q]$ is not a cap, $[\varphi_a]$ is reachable from it in $\boldsymbol{p}\mathcal{Q}(\delta)$. By the construction of K, $[q]$ has exactly a single parent in K. Thus, we conclude K is a tree. Let $[q]$ be a non-empty position in $\boldsymbol{p}\mathcal{Q}(\delta)$. Whenever support fronts are removed from $[q]$ in the construction of K, $[q]$ retains one support front. So, $[q]$ remains to be a vertex in K.

$\square$

Proof for (2). We first show H is a tree. Since $\boldsymbol{m}\mathcal{Q}(\delta)$ is acyclic, by the construction of H, H is acyclic. Note that $[a] \in V(H)$. As $[a]$ is a cap, it has no parents. It suffices to show that every vertex of H other than $[a]$ has exactly a single parent: as H is acyclic, $[a]$ would then be reachable from every vertex of H. Let $[b]$ be a vertex of H other than $[a]$. Since $[b]$ is not a cap, $[a]$ is reachable from it in $\boldsymbol{m}\mathcal{Q}(\delta)$. By the construction of H, $[b]$ has exactly a single parent in H. Thus, we conclude H is a tree. Let $[b]$ be a non-cap theme in $\boldsymbol{m}\mathcal{Q}(\delta)$. Whenever a support front is removed from $[b]$ in the construction of H, a base front is added to it. So, $[b]$ remains to be a vertex in H.

$\square$

Proposition 5 (Hierarchy Duality). Let δ an acyclic, closed and properly rooted thematic network.

(1) The thematic dual of a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$ is a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$.

(2) The position dual of a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$ is a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$.

Proof for (1) and (2). Let K be a position hierarchy of $\boldsymbol{p}\mathcal{Q}(\delta)$ rooted at $[\varphi_a]$, and H a thematic hierarchy of $\boldsymbol{m}\mathcal{Q}(\delta)$ rooted at $[a]$. Let δ' be a thematic network obtained from δ by removing all cap clauses other than a-clause. Note that δ' is closed as δ is closed and properly rooted. Note also that the construction of δ' is equivalent to the Step 1 in Definitions 5 and 6. Let σ be a function that selects, given a position of δ' having two or more support themes, all but one of its support themes. Let δ^a be a thematic network given by:

$$X_{\delta^a} = X_{\delta'} - \bigcup_{q \in P'} \{(q, a_i)^N\}_{a_i \in \sigma(q)} \cup \bigcup_{q \in P'} \{(\varphi_{a_i}, a_i)^N\}_{a_i \in \sigma(q)}$$

where P' is the set of all positions of δ' having two or more support themes. Note that the construction of δ^a from δ' corresponds to the Step 2 in Definitions 5 and 6. Thus, we have $G = \boldsymbol{p}\mathcal{Q}(\delta^a)$ and $H = \boldsymbol{m}\mathcal{Q}(\delta^a)$. Note also that δ^a is closed. By Proposition 2 (Quotient Duality), we obtain

- $\Delta^{\boldsymbol{m}}(K) = \Delta^{\boldsymbol{m}}(\boldsymbol{p}\mathcal{Q}(\delta^a)) = \boldsymbol{m}\mathcal{Q}(\delta^a) = H$
- $\Delta^{\boldsymbol{p}}(H) = \Delta^{\boldsymbol{p}}(\boldsymbol{m}\mathcal{Q}(\delta^a)) = \boldsymbol{p}\mathcal{Q}(\delta^a) = K$

□