From Enterprise Concepts to Formal Concepts : A University Case Study

CAINE, Jamie <http://orcid.org/0000-0001-8353-6529> and POLOVINA, Simon <http://orcid.org/0000-0003-2961-6207>

Metadata of the chapter that will be visualized in SpringerLink

Book Title	Graph Structures for Knowledge Representation and Reasoning
Series Title	
Chapter Title	From Enterprise Concepts to Formal Concepts: A University Case Study
Copyright Year	2018
Copyright HolderName	Springer International Publishing AG, part of Springer Nature

Author	Family Name	**Caine**
	Particle	
	Given Name	**Jamie**
	Prefix	
	Suffix	
	Role	
	Division	Conceptual Structures Research Group, Department of Computing, Communication and Computing Research Centre
	Organization	Sheffield Hallam University
	Address	Sheffield, UK
	Email	j.caine@shu.ac.uk
	ORCID	http://orcid.org/0000-0001-8353-6529
Corresponding Author	Family Name	**Polovina**
	Particle	
	Given Name	**Simon**
	Prefix	
	Suffix	
	Role	
	Division	Conceptual Structures Research Group, Department of Computing, Communication and Computing Research Centre
	Organization	Sheffield Hallam University
	Address	Sheffield, UK
	Email	s.polovina@shu.ac.uk
	ORCID	http://orcid.org/0000-0003-2961-6207

Abstract	A business enterprise is more than its buildings, equipment or financial statements. Enterprise Architecture frameworks thus include a metamodel that attempts to bring together all the enterprise concepts including the visible entities into a unified conceptual structure. Using a case study based upon the institution of the authors, the effectiveness of this conceptual structure is explored in two fold. Firstly, a simple example using familiar concepts such as the physical location of the authors' institution. Secondly, a more detailed example that includes the key enterprise concepts that currently exist within that institution. The metamodel is stated in Conceptual Graphs then mapped from these graphs' triples into transitive Formal Concept binaries using the *CGFCA* software. Misalignments within the enterprise concepts discovered from the derived formal concepts are highlighted in both case examples, hence pointing towards the wider applicability of this approach.

From Enterprise Concepts to Formal Concepts: A University Case Study

Jamie Caine and Simon Polovina(✉)

Conceptual Structures Research Group, Department of Computing,
Communication and Computing Research Centre,
Sheffield Hallam University, Sheffield, UK
{j.caine,s.polovina}@shu.ac.uk

Abstract. A business enterprise is more than its buildings, equipment or financial statements. Enterprise Architecture frameworks thus include a metamodel that attempts to bring together all the enterprise concepts including the visible entities into a unified conceptual structure. Using a case study based upon the institution of the authors, the effectiveness of this conceptual structure is explored in two fold. Firstly, a simple example using familiar concepts such as the physical location of the authors' institution. Secondly, a more detailed example that includes the key enterprise concepts that currently exist within that institution. The metamodel is stated in Conceptual Graphs then mapped from these graphs' triples into transitive Formal Concept binaries using the *CGFCA* software. Misalignments within the enterprise concepts discovered from the derived formal concepts are highlighted in both case examples, hence pointing towards the wider applicability of this approach. AQ1

1 Introduction

A business enterprise is more than just the sum of its buildings, equipment or financial statements. Such visible entities are simply the structures that follow from its strategy, which is just as real. Strategy is moreover the driving entity, without which the enterprise falters. Like many other disciplines, business modelling practitioners (such as enterprise architects) rely on useful conceptual models that underpin enterprise activity. The underlying enterprise concepts in these models capture the purpose of the enterprise (why it exists) and articulated through its strategy. To achieve its strategic goals, the enterprise concepts extend into the enterprise's lower level tactical and operational goals that include its locations, finance, assets (e.g. buildings, trading stock, information technology), staff and an organisational structure. History however continues to show these entities becoming the drivers resulting in the emergence of bureaucratic structures, inter-departmental conflicts, inadequate computer systems and other experiences where we have 'The tail wagging the dog' i.e. strategy is lost and ends up following structure [3]. Put another way, the operational enterprise concepts overtake the strategic enterprise concepts when it should be the other way round.

M. Croitoru et al. (Eds.): GKR 2017, LNAI 10775, pp. 1–13, 2018.
https://doi.org/10.1007/978-3-319-78102-0_5

To address this phenomenon the paper is structured as follows. Enterprise concepts are introduced and discussed through the notion of enterprise architecture and the formal depiction of the enterprise concepts through ontology, semantics and metamodels. The relevance and use of Conceptual Structures is then addressed by illustrating two examples of the same case study, Sheffield Hallam University (SHU) being the institution of the authors. The first example is a simplified example with reference to a simple structured metamodel. The second example reflects a more accurate depiction of the concepts and transitive aspects that embody SHU's strategy [16]. This entails a decomposition of the SHU strategy by starting with an uppermost concept 'Forces and Trends' that influence strategy and ends in Process Performance Indicator (PPI). This section also explicates Conceptual Graphs (CGs), Formal Concept Analysis (FCA) and the *CGFCA* software and how they are used. For both examples, FCA Lattices generated from the CGs are iterated to correct the model (and metamodel in the simplified SHU example). It is through the corrections that we further understand the value that formal concepts bring to enterprise concepts. This is followed by a discussion of the further significance of this work, culminating in the paper's conclusions.

2 Enterprise Architecture

Enterprise Architecture (EA) recognises that enterprises are best understood by a holistic approach that explicitly refers to every important issue from every important perspective [20]. Hence all the enterprise concepts need to relate to each other.

2.1 Ontology, Semantics and Metamodels

EA arose from Zachman's original Information Systems Architecture Framework [12,20]. Zachman's EA framework places the enterprise concepts in cells that are interrelated through a simple two-dimensional matrix, consequently referred as an enterprise ontology [14,19]. The Open Group Architecture Framework (TOGAF) articulates the semantics in such an ontology by formally defining the relations between the enterprise concepts (entities) in a content metamodel rather than simply relying on their position in a matrix (or table) like Zachman [4,5]. A metamodel is the model about the model. The TOGAF metamodel formally describes the model to which every enterprise conforms, thereby embodying enterprise concepts. The EA metamodels have been comprehensively enhanced by the enterprise standards body LEADing Practice in association with the Global University Alliance [1,11].

3 Conceptual Structures

In his seminal text, Sowa describes Conceptual Structures (CS) as "Information Processing in Mind and Machine" [15]. Enterprises essentially arise as acts of human creativity in identifying business opportunities or other organisational solutions to social needs (e.g. government bodies, charities, schools or universities to name a few). Formal depictions of the metamodels (and the models that they in turn represent) enable them to be computable. Software tools potentially bring the productivity of computers to bear on interpreting the enterprise concepts, offering more expressive knowledge-bases leading to better decision-making. CS brings human creativity and computer productivity into the same mindset; CS thus offers an attractive proposition for capturing, interrelating and reasoning with enterprise concepts.

3.1 A Simplified Case Study of SHU

To clarify the approach, and explore the value of CS to enterprise concepts, a simple case study is now presented. For ease of understanding a much-simplified metamodel is used as well as a simplified description of the case study, which is Sheffield Hallam University (SHU) where the author of this paper is employed. SHU is a large public university located in Sheffield in the UK. Remembering that the term enterprise does not only apply to profit-making businesses, SHU's strategy is epitomised by the term 'Transforming Lives'. SHU meets this strategy through its location in Sheffield and the staff it employs (noting that these aspects are chosen from all its visible entities for simplicity.) The success of its strategy as realised through its staff and location (in this simplified example) is measured by Key Performance Indicators (KPIs). One such KPI in the UK is the National Student Survey ('the NSS', www.thestudentsurvey.com).

3.2 Conceptual Graphs

To demonstrate CS, Sowa devised Conceptual Graphs (CGs). CGs are essentially a system of logic that express meaning in a form that is logically precise, humanly readable, and computationally tractable. CGs serve as an intermediate language for translating between computer-oriented formalisms and natural languages. CGs graphical representation serve as a readable, but formal design and specification language [7,13].

Figure 1 reveals that CGs follow an elementary concept→relation→concept structure, which describes the ontology and semantics of the enterprise concepts as explained earlier. The CGs are thus directed graphs that capture the metamodel at the logical level including its direction of flow. Figure 1's left-hand side CG is the metamodel for our simple example, and the right-hand side is the specialised model for SHU that conforms to the metamodel. The type label `Vision & Mission`, `Enterprise`, `Place`, and `KPI` are each specialised by gaining a defined referent, which is an instantiation of the type label. The referent is `2020-Strategy.docx` (a written document), `Sheffield Hallam University` (the enterprise), `Sheffield` (SHU's location) and {`NSS-data...`} (a structured

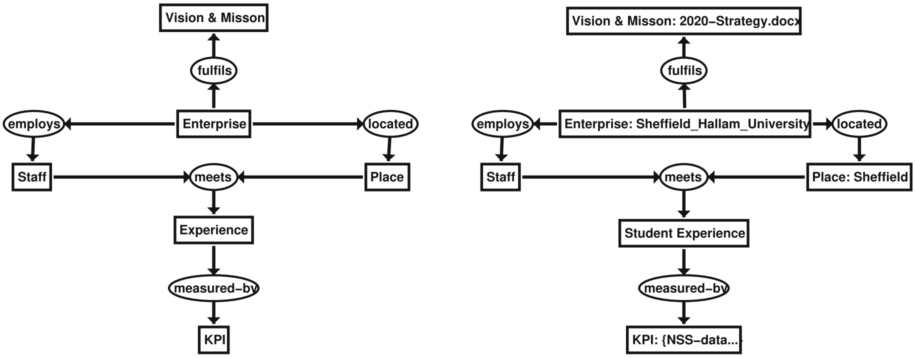


Fig. 1. Metamodel and SHU, in CGs

data source) for each type label respectively[1]. The type label `Experience` was specialised to `Student Experience`, which is `Experience`'s subtype.

3.3 An Expanded Example of the SHU Case Study

The expanded example depicts SHU's 'Transforming Lives' strategy and the distinctive four strategic pillars that it encompasses [16]. Due to becoming too large by being represented as one large CG (Conceptual Graph), the CGs for this example are shown by four modularised CGs i.e. Figs. 2, 3, 4 and 5.

These modified CGs have duplicate referents that are hence co-referent. The CGs can thereby be rejoined through the CGs join operation from their co-referent links [13]. These CGs draw upon the LEADing Practice Strategy Metamodel reference content [11,17].

Traditional strategy formulation accommodates the impact that forces and trends can have on organisational strategy [10]. Given this more accurately describes SHU's Enterprise Architecture, the concept of forces and trends are included within this model. Each strategic pillar is realised through goals and objectives that are each then measured by a Key Performance Indicator (KPI) that is current to SHU's strategy. Each KPI then measures a function followed by the role performing the function that in turn delivers a service. The model culminates in the Process Performance Indicator (PPI) concept that addresses each process deriving out of each strategic pillar in one PPI concept.

[1] { } denote 'plural' referents, meaning they hold more than one referent. Here NSS-data may be one of many datasets that collectively provide KPIs of SHU's strategy and shown simply to illustrate multiple cardinality of concepts. The Staff type label would also have a plural referent to depict the many staff that SHU employs. Plural referents are however not elaborated further for this simple case study's purposes.

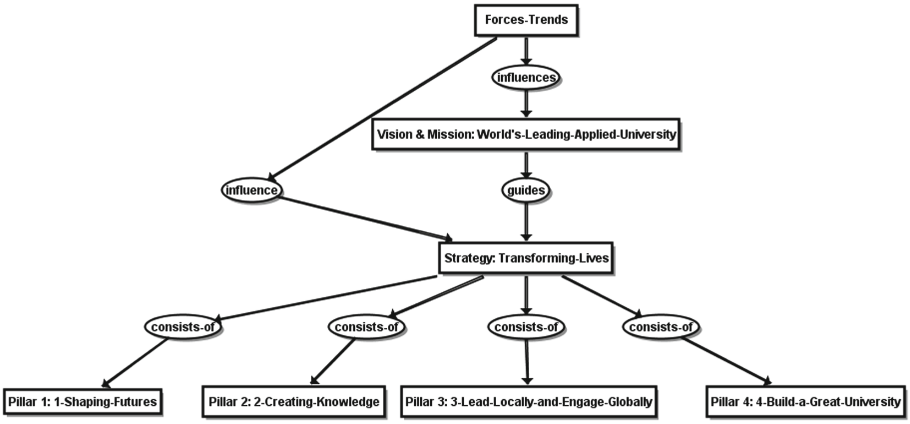


Fig. 2. Modified SHU part 1 of 4, in CGs

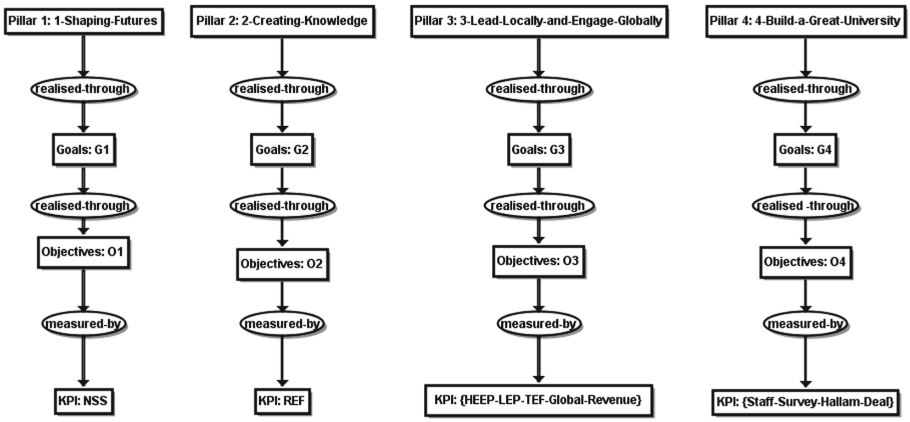


Fig. 3. Modified SHU part 2 of 4, in CGs

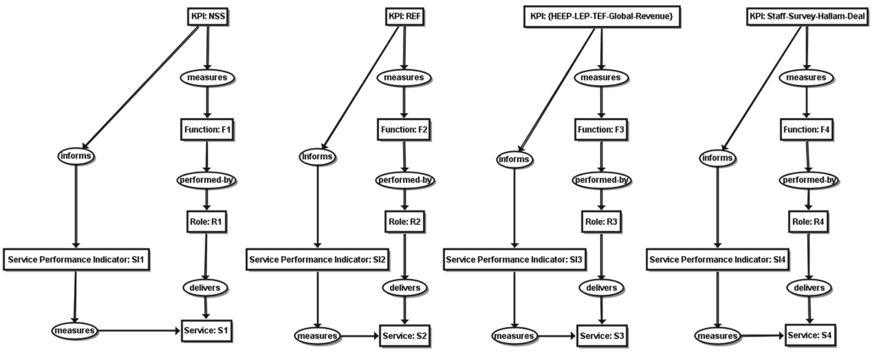


Fig. 4. Modified SHU part 3 of 4, in CGs

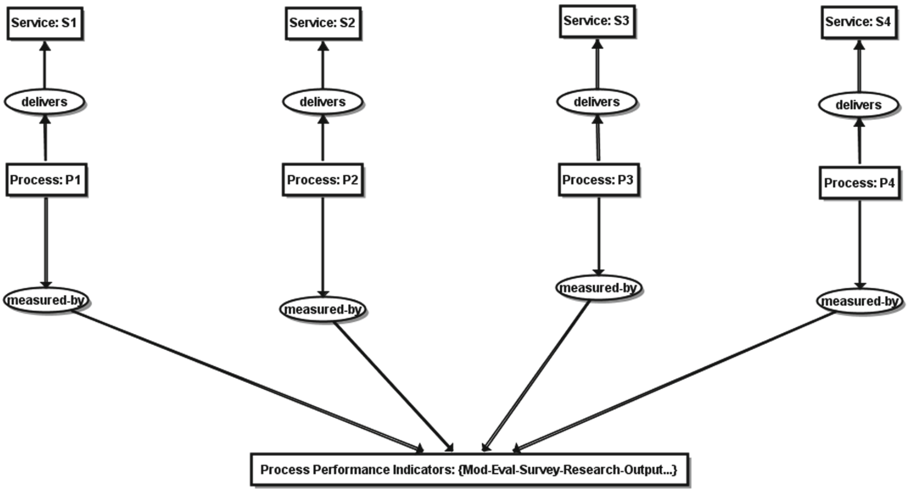
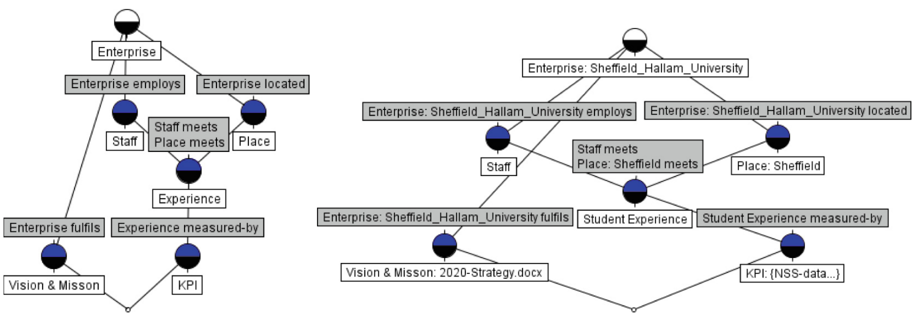


Fig. 5. Modified SHU part 4 of 4, in CGs

3.4 Formal Concept Analysis

Formal Concept Analysis (FCA) adds a mathematical level to the logical level captured in CGs [6]. The FCA formal context is generated from the CGs by the *CGFCA* software[2] [2]. Essentially, this software transforms CGs' underlying concept→relation→concept triples structure into source-concept⌒relation→target-concept binaries thereby making them suitable for FCA. Figure 6 shows the corresponding FCA lattice (i.e. Formal Concept Lattice) that results from this transformation of the corresponding CGs in Fig. 1 from the simple SHU case study. The lattice for the four joined CGs for the expanded example are given by Fig. 7.



(a) Metamodel (b) SHU

Fig. 6. Metamodel and SHU, Formal Concept Lattice (FCL) for each

[2] https://sourceforge.net/projects/cgfca/.

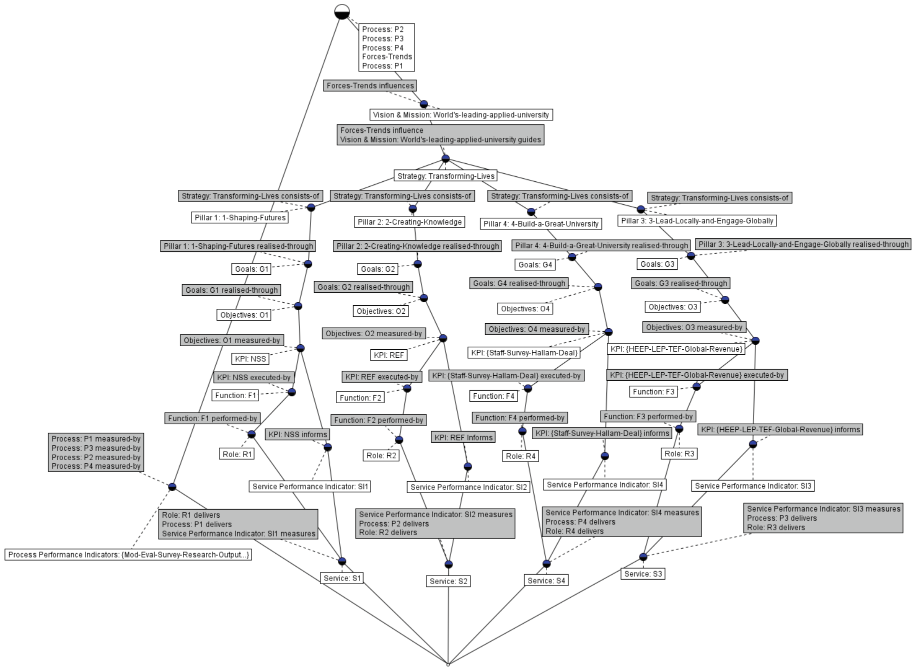


Fig. 7. Modified SHU combined, FCL

4 Iterating Enterprise Concepts from Formal Concepts

We can see that the *infimum* (bottommost) formal concept in Fig. 6 doesn't have its own labels. We will now explore why this is significant.

4.1 An Architectural Principle

As stated earlier, EA takes a holistic perspective. To draw from a building architect's analogy, architecture ranges "From the blank piece of paper to the last nail in the wall." Likewise EA (Enterprise Architecture) follows the same principle; indeed an enterprise is set by its vision and mission (articulated in its strategy) and–taking the analogy to the same extent–applies it to every asset it owns.

4.2 Transitivity of Enterprise Concepts

In reality we would not evaluate every asset to such an extreme, but it demonstrates that enterprise concepts follow a transitive path from the highest level purpose of the enterprise, percolating through its strategic, tactical and operational enterprise concepts as interconnected by their semantic relations to its most specific assets that determine its success. There should be an overall flow from the very top to the very bottom with every concept and relation thus interlinked along the way. In the simple SHU case study, the 'culprit' is the `fulfils` relation in Fig. 1, evident by the upward direction that the arrows point up to `Vision & Mission` from `Enterprise`. All the other arrows point downwards. A formal concept lattice has a *supremum* (topmost) concept and an *infimum* (bottommost) concept. Notably though, the *infimum* has no labels, so what is it's "...to..." enterprise concept? The CGs suggest it's `KPI`, But it's one of the formal concepts above in the lattice. The answer is that the enterprise concepts in Fig. 1 are not all transitive thereby do not concur with the architectural principle. In the expanded SHU case study in Fig. 5 Process delivers a Service, highlighted by the arrow pointing upwards. In fact it should be pointing downwards as `Service` is delivered by a `Process`. It is the `Service` that needs to be changed before the process to ensure that the `Process`' outcome reflects the intended goal [18]. Remember that the metamodel would needed to be validated first, in order to verify any model that is populated from it (as illustrated by the simplified SHU example).

4.3 Correcting the Transitivity

SHU Simple Case Study. Referring to the simple case study (but remembering that SHU is in fact a much more sophisticated enterprise as the more detailed case study identifies), the direction of the arrows around the `fulfils` relation simply need to change direction as stated. This correction is given by Fig. 8, which also shows the `fulfils` relation has become `fulfilled-by`. Although it's a simple renaming in this case, the metamodel (and the SHU model) is fully transitive i.e. architectural. FCA, through *CGFCA* identified this architectural gap. The CGs are conventionally generated by hand, akin to how metamodels and models are developed in many EA software tool environments[3]. As indicated

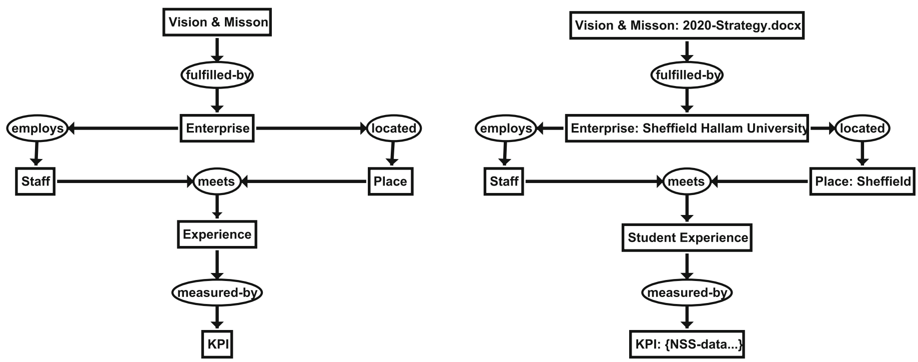
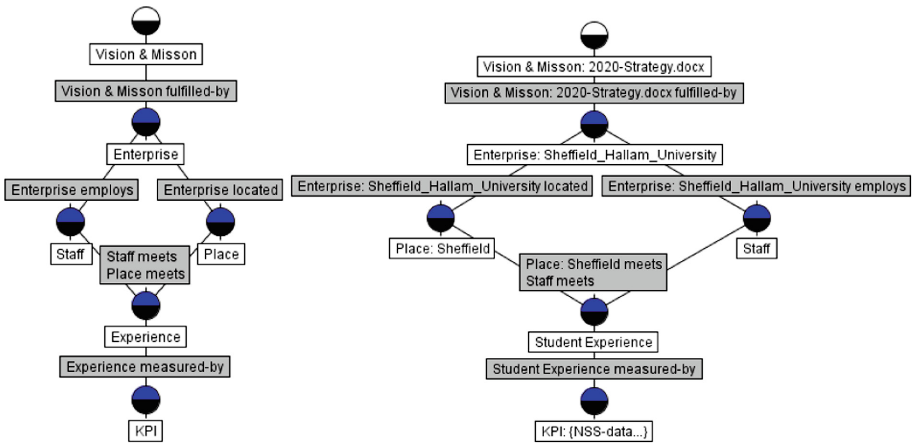


Fig. 8. Corrected metamodel and SHU, in CGs

[3] The tools tend to depict the models and metamodels in other notations such as UML (www.uml.org), but this underlying remark still holds true.



(a) Metamodel (b) SHU

Fig. 9. Lattices, after correction

earlier, CGs graphical representation serve as a readable, formal design and specification language at a logical level but FCA adds rigour at a mathematical level that allows the formal concepts to be computer generated. The productivity of computers has been applied to the creativity of human thinking—the rationale for conceptual structures (CS).

SHU Extended Case Study. For the expanded SHU example, Fig. 10 shows that two aspects were changed in one of the original four CGs (i.e. part 4) to

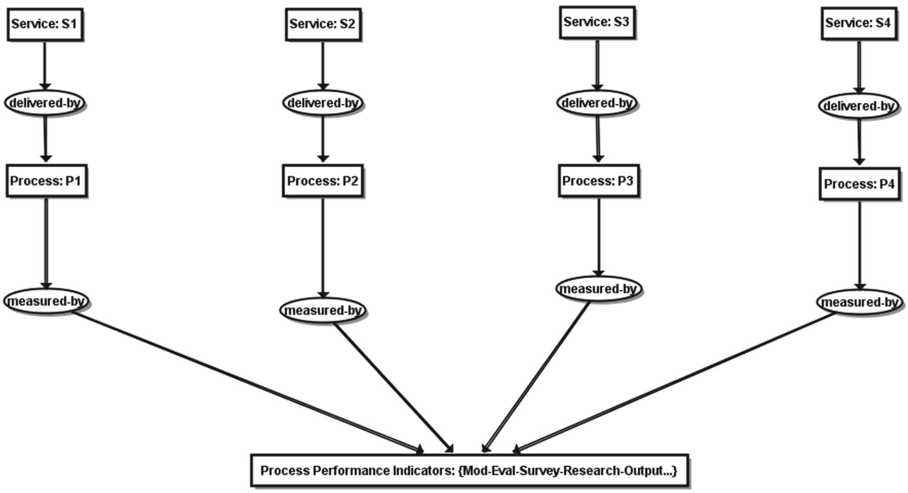


Fig. 10. Corrected SHU 4, in CGs

correct the CG in order to generate a lattice that displays the pathways from the uppermost concept 'Forces and Trends' down to the bottommost concept, PPI.

The first change was the direction of the arrow to represent the correct directional flow between service and process. Then semantic relationship (the second change) is: `[Service]` → `(delivered-by)` → `[Process]` for all the respective referents i.e. `S1` to `S4`, and `P1` to `P4`. This correctly describes the semantic relationship between the concepts and through this the formal concept lattice (Fig. 11) reflects the correct transitivity from *supremum* (topmost) to *infimum* (bottommost) like the simple example, Fig. 9.

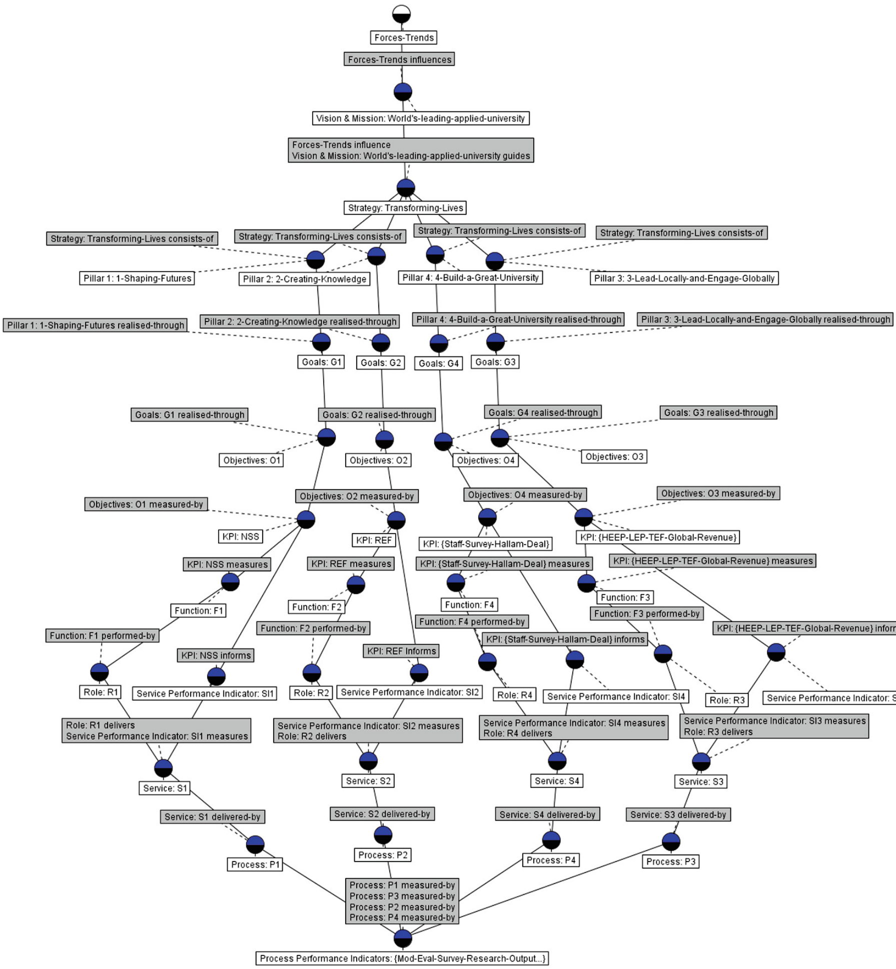


Fig. 11. Corrected SHU combined, FCL

5 Discussion

The significance of the change of arrow direction and relation renaming described above has demonstrated the correct transitivity in relation to the enterprise (SHU) and its strategy. The expanded case example demonstrates a transitive flow that reflects concepts that all connect to the forces and trends which ultimately influence the enterprise strategy. The "...last nail in the wall" *infimum* formal concept `PPI` brings together all the enterprise concepts to show how they are all (ultimately) measured, hence evaluated and managed for achieving SHU's purpose.

Of course, a straightforward visual inspection of the CGs would reveal that the arrows would all need to be in a fully transitive direction as described. But the two SHU case studies (one simple the other expanded) demonstrate the principle. In reality, and as even the simplified SHU case indicates, the metamodels and models can run to many hundreds and even thousands of interlinked enterprise concepts and their semantic relations. An examination of metamodel libraries for example reveals their possible extent [4,11]. There are also other comprehensive examples that support the *CGFCA* approach [2,8,9]. Therefore trying simply to inspect the hand-drawn models for misalignments in the enterprise concepts with the human eye would become an arduous if not impossible task, whereas the mathematically, computer generated formal concepts from FCA and *CGFCA* would find them in an instant. Although we have increased the total concepts to forty and made a change between process and service, the expanded case example demonstrates the principle in the likelihood of greater-sized CGs and the changes made to them. Meanwhile we can easily sense how the transitivity of all enterprise concepts can be identified by restating them as formal concepts. It is hence our intention to further explore the enterprise concepts for SHU as formal concepts using *CGFCA*.

6 Conclusions

Enterprise concepts benefit from FCA through *CGFCA*. Following the architectural principle of "The blank piece of paper to the last nail in the wall", *CGFCA* discovers the transitivity in the enterprise concepts, highlighting where that transitivity is deficient. For enterprise concepts articulated through enterprise architecture, the transitivity extends throughout including the *infimum* formal concept. By aligning enterprise concepts with formal concepts, an enterprise's visible entities such as its buildings, equipment or financial statements can thus be directed to support rather than hinder the enterprise. It also serves to remind business enterprises that structure follows strategy; the enterprise's organisational form is the *outcome* of its purpose ('vision and mission').

CGFCA is actually *triples* to *binaries* through FCA. This opens its potential to be generalised to other, more widely-used notations that enterprise modellers take advantage of such as UML Class Diagrams that use directed graphs (which are commonly found in EA metamodels). Going even wider, RDFS and OWL from the Semantic Web or any other notation that uses directed triples could benefit too. The experiences from applying *CGFCA* to enterprise metamodels has also raised these additional avenues. Aligning computer productivity with human creativity is a tenet of conceptual structures, and we have shown that FCA in this sense can be brought to bear to make it so.

References

1. Global University Alliance: Industry standards research: the value of applying standards to increase the level of reusability, replication and standardization (2018). http://www.globaluniversityalliance.org/wp-content/uploads/2017/10/Global-University-Alliance-Research-Industry-Standard.pdf
2. Andrews, S., Polovina, S.: A mapping from conceptual graphs to formal concept analysis. In: Andrews, S., Polovina, S., Hill, R., Akhgar, B. (eds.) ICCS 2011. LNCS (LNAI), vol. 6828, pp. 63–76. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-22688-5_5
3. Chandler Jr., A.D.: Strategy and Structure: Chapters in the History of the American Industrial Enterprise. MIT Press, Cambridge (1962)
4. The Open Group: 34. Content metamodel (2011). http://pubs.opengroup.org/architecture/togaf9-doc/arch/chap34.html
5. Gruber, T.R.: A translation approach to portable ontology specifications. Knowl. Acquis. **5**, 199–220 (1993)
6. Hitzler, P., Scharfe, H.: Conceptual Structures in Practice. CRC Press, Boca Raton (2009)
7. Polovina, S.: An introduction to conceptual graphs. In: Priss, U., Polovina, S., Hill, R. (eds.) ICCS-ConceptStruct 2007. LNCS (LNAI), vol. 4604, pp. 1–14. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-73681-3_1
8. Polovina, S., Andrews, S.: CGs to FCA including Peirce's Cuts. Int. J. Concept. Struct. Smart Appl. (IJCSSA) **1**(1), 90–103 (2013)
9. Polovina, S., Scheruhn, H.-J., von Rosing, M.: Modularising the complex metamodels in enterprise systems using conceptual structures. In: Sugumaran, V. (ed.) Developments and Trends in Intelligent Technologies and Smart Systems, pp. 261–283. IGI Global, Hershey (2018). ID: 189437 AQ2
10. Porter, M.E.: How competitive forces shape strategy. Harv. Bus. Rev. **57**(2), 137–145 (1979). Article on the Positioning School of Strategy
11. LEADing Practice: Meta model reference content #LEAD-ES20021ALL (2018). http://www.leadingpractice.com
12. Roger Sessions: A comparison of the top four enterprise-architecture methodologies (2007). http://msdn.microsoft.com/en-us/library/bb466232.aspx
13. Sowa, J.F.: Conceptual graphs. In: van Harmelen, F., Lifschitz, V., Porter, B. (eds.) Handbook of Knowledge Representation. Foundations of Artificial Intelligence, vol. 3, pp. 213–237. Elsevier, Amsterdam (2008)
14. Sowa, J.F., Zachman, J.A.: Extending and formalizing the framework for information systems architecture. IBM Syst. J. **31**(3), 590–616 (1992)
15. Sowa, J.F.: Conceptual Structures - Information Processing in Mind and Machine. The Systems Programming series. Addison-Wesley, Reading (1984)
16. Sheffield Hallam University: Transforming lives (2017). http://www.shu.ac.uk/strategy

17. von Rosing, M., Fullington, N., Walker, J.: Using the business ontology and enterprise standards to transform three leading organizations. Int. J. Concept. Struct. Smart Appl. (IJCSSA) **4**(1), 71–99 (2016). ID: 171392
18. von Rosing, M., Kirchmer, M.: Focusing business processes on superior value creation: value-oriented process modeling. In: von Rosing, M., Scheer, A.-W., von Scheel, H. (eds.) The Complete Business Process Handbook, pp. 479–496. Morgan Kaufmann, Boston (2015)
19. Zachman, J.A.: John Zachman's concise definition of the Zachman framework. https://www.zachman.com/about-the-zachman-framework
20. Zachman, J.A.: A framework for information systems architecture. IBM Syst. J. **26**(3), 276–292 (1987)

Author Queries

Chapter 5

Query Refs.	Details Required	Author's response
AQ1	This is to inform you that corresponding author has been identified as per the information available in the Copyright form.	
AQ2	Please check and confirm the inserted details are correct in Refs. [9, 13].	