1. INTRODUCTION

The process of design often involves different communities of practice and of discourse within an organisation. These communities often use different terminology and concepts from each other. Eckert et al. (2005) argue that the lack of clear communication and connectivity remains an important issue for designers and managers who often localise knowledge of the processes they are involved with to address the issue. Consequently, designers may not understand the context of the information that they are using due to the lack of overview of the design process. Salustri and Rogers (2009) contend that achieving a common language in design should be seen as a goal given that a common language will help develop a shared understanding of design across its sub-disciplines. Moreover, it will help establish design as a distinct and unique discipline.

Several disciplines are commonly involved in design. One set can be broadly termed human factors, including physical ergonomics (Tosi, 2019), cognitive ergonomics (Sheridan, 1992) and human error (Day, 2016). These disciplines deal with very different concepts from each other, so it might appear self-evident that they would use very different terminology. However, this assumption does not appear to have been systematically tested. Testing it is a non-trivial problem, because apparent matches in terminology may actually involve the same term being applied to different underlying concepts; conversely, apparently different terminology might map on to identical underlying concepts (Shaw and Gaines, 1989). In this article, we describe a methodology for systematically investigating terminology and concepts across disciplines, using methods such as downward laddering to unpack meaning systematically and map meanings onto an ontology. This methodology includes a novel method of using human skills in pattern-matching and incorporating semantics of terms from an ontology.

We are focusing initially on manufacturing design, where the communication issues are particularly clear (for instance, when translating between artistic design and specific measurements for engineering design). We expect that insights from this work will also be directly applicable to HCI design.

Ambiguity in the design process within a discipline makes it difficult to understand the characteristics of communication in general. Eckert et al. (2005) contend that it is challenging to identify communication problems in many practical design situations as they are strongly interwoven with other process issues. As such, companies often struggle to see where the problems emerge from.

A widespread problem in design is the lack of a shared terminology between the stakeholder groups involved in a design across various disciplines. Some or all of these disciplines might differ in the surface structure of their terminology but share common concepts under different names (Shaw and Gaines, 1989). Potentially, this may improve the chances of producing a shared terminology that could be used across the design process, reducing misunderstandings and miscommunication, improving safety, facilitating sharing designs more explicitly and increasing interoperability. As stated by Salustri and Rogers (2009), having a common design language may not limit expression, while it can provide a framework for communicating...
effectively, which should in turn be very beneficial in establishing a distinct discipline of design.

Differences in design terminology can lead to misunderstandings and failures of communication, which in turn can lead to undesired outcomes. In a worst case, design failures can lead to deaths (Leveson and Turner, 1993), so improving design communication has significant consequences.

An obvious way of improving this situation is to create a shared core set of terminology within the design chain.

However, this is far from easy. First, it is necessary to collate and understand the terminology used by different communities within the chain. One approach to achieve this goal is with content analysis (Krippendorff, 2013), based on the words used by each community. Content analysis may take various forms. In the following sections, we examine increasingly sophisticated forms and discuss their implications. We then demonstrate a semantically-aware approach to develop shared terminologies using content analysis.

2. BASIC CONTENT ANALYSIS VIA WORD CLOUDS

A popular and simple form of content analysis is the word cloud, as in the image below. In this representation, the size of each word corresponds to its frequency in a given text. The example below was generated using WordCloud Generator, applied to an arbitrarily chosen text on design (Bjögvinsson, Ehn and Hillgren, 2012). In the image below, the most common word is "design". The words "things" and "stakeholders" are moderately common.

![Figure 1: A word cloud from two texts on design](image)

Although this representation conveys some information about the text, it has very limited semantics, and has correspondingly limited power. For example, the location of a word within a word cloud is essentially arbitrary, so the viewer of a word cloud is not immediately able to see whether there are differences in the frequency distributions of terms across two different texts. Representing the same information as a histogram of the relative frequency of the terms, however, makes it much easier to make such comparisons, as shown below:

![Figure 2: A histogram of relative frequency of the terms in the word cloud](image)

The most common term is “design” (277 occurrences); the least common terms include “city of malmö” and “network of working”, which occur 3 and 2 times. Displaying the relative frequencies of the terms from the two design papers as a histogram shows that they follow a Zipf-style distribution, which is not visible via the word cloud.

3. CONTENT ANALYSIS AND UNDERLYING SEMANTICS

There are also challenges related to the use of terms. Two communities may use the same word with different meanings, or different words with the same meaning. The permutations for this can be represented as a table, as shown below (Shaw and Gaines, 1989).

| Table 1: Terminology and meaning |
|---------------------------------|
| **Same word** | **Different word** |
| **Same concept** | Consensus | Correspondence |
| **Different concept** | Conflict | Contrast |

This has been described as a serious issue for requirements engineering (Shaw and Gaines, 1989), and is likely to be a significant issue in design terminology. It is therefore necessary not only to tabulate the words being used, but also the meanings of the words.
4. CONTENT ANALYSIS AND ONTOLOGIES

In tabular content analysis, this can be handled via aggregation of terms, for instance, via initial tabulation of the actual terms used (verbatim) followed by coding these terms into higher-level groups (e.g. gist, where two or more terms have the same meaning, and superordinate, where two or more gist terms are related in some way). For example, “red” and “green” do not have the same meaning but are both colours (Petre and Rugg, 2007).

Table 2 below shows a content analysis, conducted by the authors particularly for this research project, of two arbitrarily chosen articles about design (Fuchs and Orbrist, 2010; Rosenhalz et al., 2009), for terms potentially relating to stakeholders.

Table 2: A content analysis table of two texts on design

| Verbatim         | Gist          | Superordinate                             |
|------------------|---------------|-------------------------------------------|
| Stakeholder      | Customer/client | System stakeholders                       |
| Customer         |                |                                           |
| Client           |                |                                           |
| User             | Users          |                                           |
| Human users      |                |                                           |
| End user         |                |                                           |
| Individual user  | Policy maker   |                                           |
| Policymaker      | Potential      |                                           |
| Citizens         | external       |                                           |
| Community        | stakeholders   |                                           |
| Individual community |            |                                           |
| Social community | Developers     |                                           |
| Developers       | Designers      |                                           |
| Codesigner       |                |                                           |
| Designer         |                |                                           |
| Participant      |                |                                           |
| Researcher       |                |                                           |
| Practitioner     |                |                                           |
| Actors           |                |                                           |

A problem with this approach is knowing just what the original author or authors mean by a particular term, such as “individual user” as opposed to “user” in the table above. In some disciplines, it is standard practice to make explicit use of a specified standard set of definitions to avoid this sort of uncertainty.

One way of eliciting meaning systematically is to use laddering (Hinkle, 1965, Rugg and McGeorge, 1995). This approach unpacks meaning via successive layers of explanation until the questioning bottoms out in terms that cannot be unpacked any further, such as numbers, names of shapes, names of colours, or the participant saying that they are unable to explain any further (Rugg and McGeorge, 1995). This form of laddering explicitly uses a graph theoretic knowledge representation, making it compatible with various forms of software support.

A related body of knowledge for handling the problem of meaning versus terminology is the literature on ontologies (Gruber, 1995). This approach has the affordance of lending itself to online support for the design communities, with software enabling the unpacking and explanation of technical terms within the ontology.

Arp et al. (2015) define ontology as a representational artifact, which comprises a taxonomy whose representations are intended to designate some combination of universals, defined classes, and certain relations between them. Moreover, it is becoming an increasingly dominant strategy for organizing scientific information, which is often understood as a controlled vocabulary for representing the types of entities and their relationships in a given domain (Shadbolt et al., 2006). Ontological models can be used in design projects to formalise a domain of interest in a comprehensive and detailed manner with the help of a conceptual scheme, which usually consists of a structure containing all the relevant classes of objects and their relations (Globa et al., 2018).

However, in practice the communities in the design chain are likely to make implicit or explicit use of two or more viewpoints (e.g. health and safety, versus ease of manufacture) in ways that have implications for unpacking and explaining technical terms. For instance, "elegant" from the viewpoint of ease of use may have very different implications from the viewpoint of ease of manufacture.

A well-established way of handling this issue is to use facet theory, which in effect allows unpacking of concepts by treating them as separate explanatory hierarchies that are elicited via laddering (e.g. Rugg and McGeorge, 1995). Figure 3 below shows an ontological view of a small set of design terms, with child nodes branching from their parent nodes. In this example, “stakeholder” is a parent node (superclass), while “user” and “customer” are child nodes (subclasses) from that parent.

![Figure 3: A simple ontology](image-url)
Assessing Commonality and Differences in Terminology Across Design Disciplines

Kanar Hama Salih • Goksel Misirli • Gordon Rugg

Cutting across these issues, however, is the problem of whether the texts being analysed contain all the relevant terminology. Much of the designers’ expert knowledge will be tacit in the strict sense or semi tacit (Maiden and Rugg, 1996). This means that the front, espoused theory, information from designers about their terminology will probably be incomplete, so any ontology based on that information will also be incomplete.

In the content analysis above, for instance, there is no distinction between within-system stakeholders and outside-system stakeholders because these terms did not occur within the texts in question. However, this distinction is important for designers, because outside-system stakeholders such as regulatory bodies can have a major effect on system design, so the ontology above includes this distinction.

Using a formalised notation like an ontology, as opposed to a verbal description, forces the notation user to make explicit choices which can have far reaching implications for the system design process. For instance, the ontology above treats the terms of “client” (in the sense of the person commissioning a product) and “user” (in the sense of the person actually using that product) as separate and non-overlapping, when these terms are defined to be disjoint in the ontology. A formalised notation can act as a valuable shared artefact for discussion between stakeholders about such choices.

This problem of missing or misleading categories can be reduced by using a systematic framework for elicitation (Maiden and Rugg, 1996) and discussions between stakeholders. However, there are obvious advantages in gathering as much information as possible automatically or semi-automatically to reduce the elicitation load on the designers. We discuss this topic in the next section.

5. CONTENT ANALYSIS AND SPATIAL STRUCTURES IN TEXTS

Quantitative content analysis typically uses an alphanumeric representation which requires significant amounts of serial processing by the human interpreting those results.

Here, we use the Search Visualiser software designed to make use of human strengths in pattern matching. This tool was developed by Rugg et al. and subsequently used in textual analysis of ancient texts (Musgrave and Rugg, 2012).

Figure 4 above shows the distribution of terms within a text about HCI design (Fuchs and Orbrist, 2010). The terms involved are related to the concept of user, and are user, stakeholder, customer, client and participant. Each square in the image represents a word in the text, starting at the top left and proceeding left to right and top to bottom of the image. Coloured squares show where a search term occurs in the text. In this example, the search terms occur frequently throughout the whole text.

The following example shows the distribution of the same search terms in a different text (Rosenhalz et al., 2009). The search terms here occur almost entirely within the first quarter of the text, with only two occurrences in the rest of the text. This difference in distribution is immediately visible in this representation, but would not be visible in a word cloud, in content analysis, or via an ontology. Search Visualiser’s design incorporates provision for other sensory outputs for user inclusion.

Figure 5: A Search Visualiser image of a text on HCI Design
The affordances of this representation enable synergy with ontologies in a novel way, as shown below.

Figure 6 below shows an example of an online search with this software. The search was for the keywords wind, wave, solar and geothermal. Both of the columns in the screenshot below show the visualisation for a document found by the software in an Internet search. These search terms would likely appear as child terms in an ontology of sustainable energy types. The document on the left shows mentions of all four keywords, as distinct layers within the column, where each layer represents a section on a particular keyword. A key feature of this document is that between the section on wind (red squares) and the section on wave (green squares), there is a section in the middle of the document where all the squares are white. This implies that the document contains a section on a source of energy which is not wind, wave, solar or geothermal. It is, in fact, a section on tidal power. If the original ontology did not include tidal power, the Search Visualiser image would have detected this absence.

This use of human pattern matching to spot a significant absence provides a way of solving the notoriously difficult Boolean NOT problem in online searches.

In summary, the approach above involves a process that begins with simple collation of specialist terms from a corpus of texts via content analysis. The meaning of these terms is unpacked via downward ladderling on explanations, to check for e.g. two different terms being used in different fields to describe the same concept. The terms are then mapped onto an ontology. The ontology is checked throughout this process for completeness both via downward ladderling and logical axioms and via the use of the Search Visualiser software.

6. CONCLUSION AND FURTHER WORK

Creating a Unified Design Language is a non-trivial problem in terms of knowledge representation and HCI. It cannot be handled by simply producing an interactive dictionary for translating between texts from different design groups; often, a term from one group (e.g. “affordance”) simply does not have an equivalent in the terminology of another group. This means that the terms in a Unified Design Language need to be defined systematically, hence our use of ontologies to provide systematic structure, and of ladderling to map concepts onto physical instantiations. It also means that the software support for such a language needs to be more than just a clickable “translate” function that a designer can use for a quick translation without interrupting the flow of a task. Instead, the online support needs to be treated as a non-trivial software system in its own right.

In addition to the knowledge representation and HCI issues associated with creating a Unified Design Language, there are also non-trivial problems involving human and organisational factors, such as conflicts between stakeholder groups. A Unified Design Language may reduce these conflicts once it is established, but the design process for this language needs to be informed by input from soft systems (Checkland, 1981) and the literature on diffusion of innovation (e.g. Rogers, 2003). The approach described above should offer a better way of handling the communication issues involved in both these areas. It also offers a possible way of solving some long-standing problems in ontology, by combining computationally tractable approaches with human skills in spatial pattern matching in a novel way.
7. REFERENCES

Arp, R., Smith, B., Spear, A. D. (2015). Building Ontologies with Basic Formal Ontology. The MIT Press, London.

Björgvinsson, E., Ehn, P. and Hillgren, P.-A. (2012). Design Things and Design Thinking: Contemporary Participatory Design Challenges. Design Issues, 28(3), pp.101–116.

Bos, W. and Tarnai, C. (1999). Content analysis in empirical social research. International Journal of Educational Research, 31(8), 659-671.

Christie, C. (2007). Content Analysis. In R. Baumeister and K. Vohs (Eds.), Encyclopaedia of Social Psychology (p. 176). Thousand Oaks, CA: Sage.

Canter, D. (1983). The potential of facet theory for applied social psychology. Quality and Quantity, 17(1).

Checkland, P.B. Systems Thinking, Systems Practice, John Wiley & Sons Ltd. 1981.

Day, R., 2016. Design Error: A Human Factors Approach. CRC Press, Boca Raton.

Drisko, J. and Maschi, T., 2016. Content Analysis. New York: Oxford University Press.

Eckert, Claudia and Maier, Anja and McMahon, Chris. (2005). Communication in Design. Design Process Improvement: A Review of Current Practice. 10.1007/978-1-84628-061-0_10.

Fuchs, C. & Orbrist, M. (2010). HCI and Society: Towards a Typology of Universal Design Principles. International Journal of Human-Computer Interaction, 26(6) pp 638-656.

Globa, L. et al. (2018) "Ontology for Application Development," in Ciza Thomas. (ed.) Ontology in Information Science. Rijeka: InTech.

Gruber, T. R. (1995) Toward principles for the design of ontologies used for knowledge sharing? Int. J. Man-Mach. Stud. 43, 907–928.

Guttman, L. (1979). New Developments in Integrating Test Design and Analysis, paper presented to the 40th International Conference on Testing Problems, Educational Testing Service New York, October 1979.

Hinkle, D. The change of personal constructs.https://www.pcp-net.org/journal/pctp10/hinkle1965.pdf

Krippendorff, K., 2013. Content Analysis: An Introduction to Its Methodology. 3rd ed. London: Sage.

Leveson, N. & Turner, C.S. (1993). An Investigation of the Therac-25 Accidents. IEEE Computer, 26(7) pp 18-41.

Maiden, N.A.M. & Rugg, G. (1996). ACRE: a framework for acquisition of requirements. Software Engineering Journal, 11(3) pp. 183-192

Musgrave, D. & Rugg, G. (2012). Visualizing textual structures. ASOR 2012 conference, Chicago

Petre, M. & Rugg, G. (2007). A gentle guide to research methods. Open University Press, Maidenhead, UK.

Rogers, E.M. (2003) Diffusion of Innovations (5th edition). Free Press, New York.

Rosenholtz, R., Twarog, N.R., Schinkel-Bielefeld, N. & Wattenberg, M. (2009). An Intuitive Model of Perceptual Grouping for HCI Design. CHI 2009, Boston.

Rugg, G. & McGeorge, P. (1995). Laddering. Expert Systems, 12(4), pp339-346.

Salustri, Filippo A. and Rogers, Damian (2009). Some Thoughts on Terminology and Discipline in Design. In: Undisciplined! Design Research Society Conference 2008, Sheffield Hallam University, Sheffield, UK, 16-19 July 2008.

Shadbolt, N., Berners-Lee, T., and Hall, W. (2006) The Semantic Web Revisited. IEEE Intell. Syst. 21, 96–101.

Sheridan, T. B. (1992). Telerobotics, Automation and Human Supervisory Control. The MIT Press, Cambridge, MA.

Tosi, F. (2019). Design for Ergonomics. Cham, Switzerland Springer.