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Using LATEX for Qualitative Data Analysis

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Abstract LATEX, in addition to its typesetting role, has considerable potential as a tool to assist in workflow automation for *Qualitative Data Analysis* (QDA) of collected research data.

1 Introduction

LATEX is a typesetting macro programming language that offers great potential for general purpose applicability [1]. LATEX is supported by many contributors who have provided macro packages suitable for common users.

In this article, we discuss and examine how LATEX can help common users to organise data for Qualitative Data Analysis. We decided to put together these notes as a means of providing some ideas to the TEX community for anyone contemplating doing something similar. The level of your understanding increases as you move through the analysis process. We couldn't find any pre-existing articles when Ivan starting working on completing a PhD.

The article is structured as follows:

- For the uninitiated readers, we briefly explain Qualitative Data Analysis;
- Our motivations for selecting LATEX for this workflow, rather than the available proprietary solutions;
- The presentation of our workflow:
  - Some useful LATEX features, such as a LATEX macro to help in flow automation;
  - Data visualisation by the use of GraphViz plots.

The QDA-workflow-by-LaTeX presented in this article helped scratch an itch that existed at the time, and we hope it will be of interest to others!

2 Qualitative Research

2.1 What is Qualitative Research?

For those not familiar with the field, *Qualitative Research* describes methods of scientific inquiry that are most commonly used in social sciences, such as the understanding of human behaviour/organisation, and the influencing factors that promote these phenomena.

The Wikipedia entry on Qualitative Research describes it as:

> *...investigating the why and how of decision making, not just what, where, when. Hence, smaller but focused samples are more often needed rather than large random samples.* [2]

Qualitative Research is composed of a number of stages, as illustrated in Figure 1:

- *Data collection* is the mechanism by which information about the social environment under investigation is faithfully captured and recorded;
- *Data reduction* refers to distilling the source material into a more compressed form amenable to drawing conclusions;
- *Data display* is concerned with organising and visualising data, such that it is immediately accessible and discernible. Humans are very proficient at categorising data [3] automatically, but it is known that 'extended text can overload human's information-processing capabilities and preys on their tendencies to find simplifying patterns' [4]. Therefore, display of data is important to ensure that the important information is captured and not overlooked;
- *Conclusion drawing* is the mechanism by which the underlying themes permeating the data are drawn to the fore, based on the work done in continual analysis. As with most of the stages in this research, the process is iteratively feeding back into subsequent stages of collection, reduction, display and conclusion drawing.

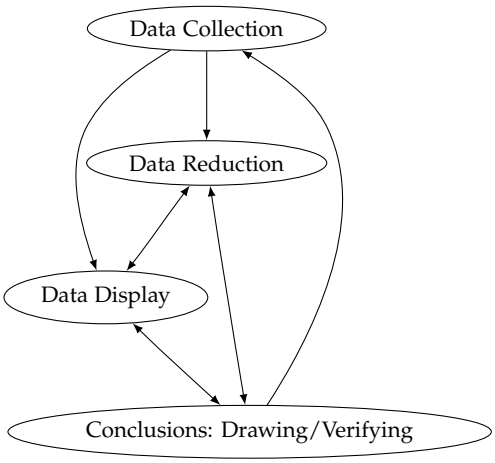

Figure 1: Components of Data Analysis: Iterative Model [4]

On the one hand, Qualitative Research is suitable to studies that are more exploratory in nature, and thus to the development of hypotheses. On the other hand, Quantitative Research is more suitable to the testing of hypothesis.

Researchers engaged in qualitative studies seek out the 'why' rather than the 'how' of its subject matter through the analysis of unstructured information[1]. It is important to carefully code this data and discern themes in a consistent and reliable manner. The process of analysing this unstructured information can be daunting and time consuming — especially so when using manual methods.

The *Grounded theory* method was developed by Glaser and Strauss [5], and is used in the exploration of a new area of research, where little pre-existing literature is available. Grounded theory consists of a number of distinct phases of research — sampling and data collection, coding and emergence of hypotheses, which are employed concurrently.

Coding is the term used for the identification of categories and concepts from the collected data [5]. The term is a fundamental step to the capturing of emergent theory from the data. In short, coding is the process of analysing the raw text, and assign representative text descriptions ('codes') to it, sentence-by-sentence or clause by clause. These representative codes are further refined, and combined into themes and categories and eventually into a theory. In essence, the research has reverse-engineered a higher level of meaning and understanding out of the

1. For example, using data sources such as interview recordings and transcripts, etc.

raw data than is apparent at first glance.

Rigorous coding (that is, coding done following the process outlined by the scientific method of grounded theory) ensures the research is scientifically analysing the data, rather than being unduly influenced by either pre-conceived ideas, or by the point of view of the interviewed participants of the study.

Coding does not wait until all the data is collected, but it is done in tandem with the data collection process so that it can influence it. Emerging themes are *constantly compared* [5] to all collected data to support the systematic discovery of theory from the data, and it is an integral defining characteristic of grounded theory. Old themes are searched for in new data, and may redirect inquiry to clarify certain aspects in new data collection. New themes that only emerge and become apparent in the latest data are searched for in the older data.

Both the original data and these emerging themes act in a feedback loop to continually improve upon the development of emerging themes, by influencing on subsequent sampling, data collection and analysis.

In order to analyse the data to identify categories and concepts, as illustrated in Figure 2, we used various coding strategies, such as open coding, axial coding, and selective coding [6]. The workflow automation we will discuss in this article specifically addresses open and axial coding. The later stages of the method (creation of memos and selective coding models) were typeset manually using Ti*k*Z/PGF.

3 Coding by Typesetting

There are many excellent software packages available for use. However, the flexibility of LaTeX ensures that we can build a workflow tailored to our own specific requirements.

To quote the great computing pioneer Alan Turing:

> *A man provided with paper, pencil, and rubber, and subject to strict discipline, is in effect a universal machine . . .* [7]

One of the nicest features of computing devices is that they don't complain about doing repetitive tasks. Automation of the manual tasks of Qualitative Research allow us to focus on making sense of our collected research data, whilst the computer takes care of the workflow mechanics.

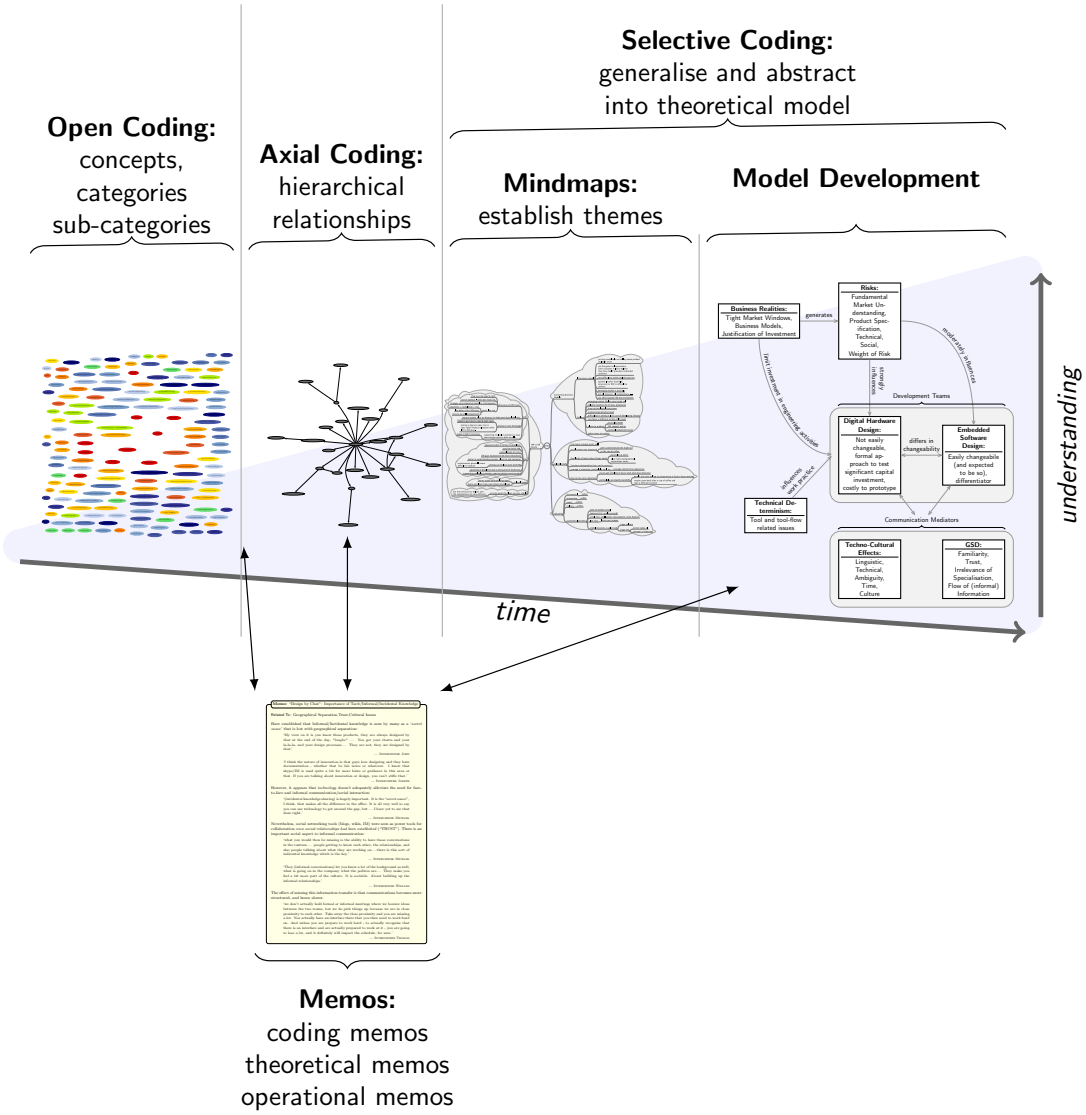

Figure 2: Grounded Theory Method

3.1 Why use LaTeX?

So, having decided that workflow automation is tremendously beneficial to our productivity as researchers, the next decision is whether to use an off-the-shelf package or cajole the workflow into LaTeX. In fact, LaTeX has a number of attributes going for it that makes its use very intriguing for QDA research:

- it keeps coding near the data:
  - *'The likelihood of keeping all or part of . . . (an) artifact consistent with any corresponding text that describes it, is inversely proportional to the square of the cognitive distance between them . . . The phrase "out of sight, out of mind" gives a vague indication of what is meant by "cognitive distance"'* [8]
  - it provides traceability from original code right through to collection, condensation, and presentation/visualisation;
- coding can easily be output as a recorded high-quality typeset deliverable — more difficult to do this with pen, paper and scissors techniques:
  - typesetting the coded data is very valuable because it allows others to check the validity of the output (theme emergence and theory building) of your work, and to provide a resource for researchers to use (subject to confidentiality and disclosure agreements);
  - Using LaTeX allows you to keep the interviews typographically consistent with the styles and notations used in the main dissertation;
- it is incredibly flexible — this is of great benefit when, for instance, you are investigating various methods of data visualisation. In the course of this research, we tried:
  - heatmaps of node hierarchies — where node size/color transfers some knowledge about the importance or frequency of a theme;
  - tag clouds — where the nodes are not structured into hierarchies, but where their size may share knowledge about their importance or frequency;
  - 3D modelling by VRML — viewing of the node hierarchy ontologies in 3 dimensions to see if it brings any new insights or allows faster assimilation of the ontology data-set as a whole;

- We looked at illustrating the progression of development of our axial coded model, on an interview-by-interview basis until it reached saturation.

When using LaTeX to process your encoded interviews, you also get them in a typeset fashion for free!

3.2 Required Tools

We use the following applications and packages to implement our QDA-workflow-by-LaTeX:

- PDFLaTeX — the typesetting engine, by which our workflow was implemented;
- Perl — a popular scripting language, which handles transforming the raw output from our LaTeX runs into various forms of visualisation;
- GraphViz [9] — a scriptable graphing system;
- GNU make — the expert system used to build the project.

In addition, the following PDFLaTeX macro packages also play their part:

- Ti*k*Z/PGF — these are sets of macros for PDFLaTeX that enable high quality illustrations;
- dot2tex [10], dot2texi.sty — macros that render GraphViz graphs in Ti*k*Z/PGF for PDFLaTeX.

3.3 LaTeX Workflow In Detail

It is now time to divulge the details of how we used LaTeX to record codes, and how, by using dot2texi.sty, we used GraphViz [9] to visualize the emerging ontology. Figure 3 gives a high-level overview of the macro steps involved in our QDA research.

All semi-structured[2] interviews were recorded using an iPod with the Griffin iTalk accessory. The recordings were then synchronised with the computer, converted to MP3's, and then downloaded via a playlist to the iPod.

2. The term *semi-structured* signifies that interviews were guided initially with a questionnaire, but allowed to lead into whatever direction naturally occurred during the interview.

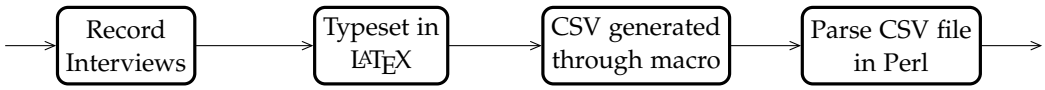

Figure 3: QDA Workflow

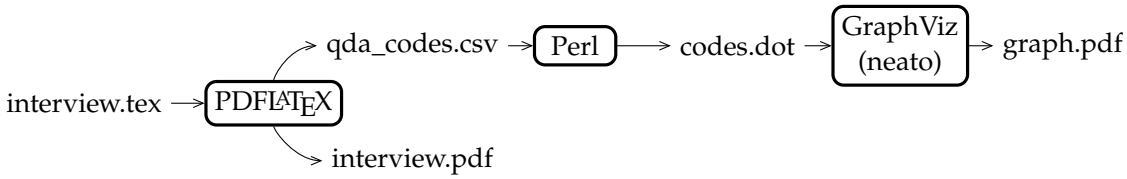

Figure 4: Typesetting Workflow

These interviews were transcribed into LaTeX, being careful to remove potentially sensitive information such as company names, site/location names, and names of individuals. This was definitely the most tedious stage of the entire endeavour.

Figure 4 illustrates in more detail the LaTeX-specific processing aspects of the workflow. At this point, the interviews were typeset using LaTeX, and hard copies printed. With a highlighter and pen. Thus, Ivan quickly manually coded the interviews — not unlike Figure 5. These initial codes were applied as markup to the LaTeX interview source.

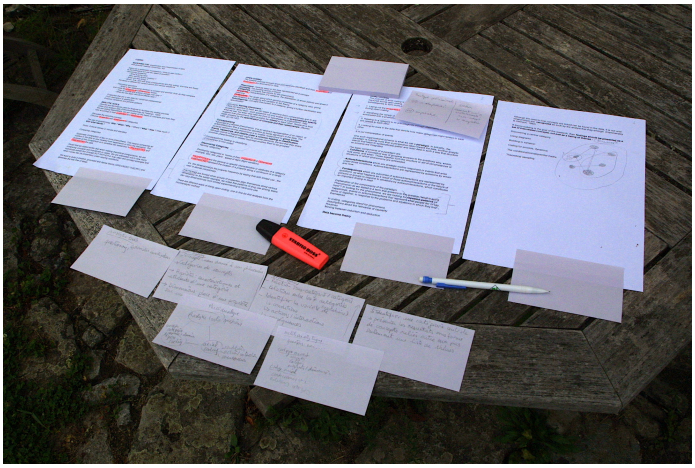

Figure 5: The Pain of Manual Methods

These marked-up interviews were processed by our custom typesetting flow again — the act of which causes the codes and associated quotations to be written to a *comma-separated-variables*-format file (CSV file, with filename suffix .csv). This is the raw coded output which is suitable for subsequent processing into a variety of visualisations. Typeset output of the interviews is also generated — with the coded text segments suitable highlighted and coded in the margin.

4 ul*q*da

Luckily for you, dear reader, the implementation of this workflow is now available on CTAN, in the form of a package called ul*q*da. Figure 6 shows an example of the use of the macros it provides, and it implements the flow described in Figure 7.

```
\section{Interview Excerpt}
  \label{section:interview}
  \textbf{IG:} Do you think the social aspect of face to face is important for the project?
  \textbf{Interviewee~XYZ:} A cup of coffee is really important because then what
  happens is that you get a real perspective. My general experience of having a
  functional group in one site, while I was in the other one, working for you and
  using video conferencing, \ulqdaCode{geographical!urgency, geographical!face-to-face}{if
  you really wanted to get things done you had to jump on a plane and fly over, there was
  nothing that could make up for sitting in a room with people to both get across the
  urgency and to ensure that communication among the team took place to address any of the
  issues.}
```

Figure 6: ul*q*da Coding Example

`\ulqdaCode{list-of-codes}{source-text}` is used to associate hierarchical lists of codes to passages of text. Each list consists of an ordered series of codes which depicted an axial relationship — with the exclamation mark '!' character separating individual codes in a hierarchy. Multiple lists are possible, with a single `\ulqdaCode` macro — each separated by a comma.

Figure 7 shows how this interview excerpt looks when it has been coded. The main text body is itself highlighted so that it stands out from surrounding text, and the codes are present in the margin.

File I/O through LaTeX can be quite slow, and the coding process can add additional processing time to the typesetting flow. Luckily, LaTeX provides the ability to determine if a file exists. We use this to check if the .csv file already exists. It doesn't change significantly across many of the multiple LaTeX runs to

IG: Do you think the social aspect of face to face is important for the project? ...

Interviewee XYZ: ...A cup of coffee is really important because then what happens is that you get a real perspective. My general experience of having a functional group in one site, while I was in the other one, working for you and using video conferencing, if you really wanted to get things done you had to jump on a plane and fly over, there was nothing that could make up for sitting in a room with people to both get across the urgency and to ensure that communication among the team took place to address any of the issues...

geographical!social, geographical!face-to-face, geographical!telecoms

Figure 7: Typeset Coded Interview Text

typeset a document, so it only needs to be generated once. This actually saves some considerable time from the build, as the QDA output otherwise can be quite slow.

```
\section{Example Visualisations}
  \ulqdaSetSectFilter{section:interview}

\subsection{Graphs}
  \begin{figure}[h]
    \centering
    \ulqdaGraph{net}{neato,mathmode, options={--graphstyle "scale=0.5,transform shape"}}
    \ulqdaGraph{flat}{neato,mathmode, options={--graphstyle "scale=0.5,transform shape"}}
    \caption{QDA Figure}
  \end{figure}

\subsection{Tabular List}
  \begin{table}[h]
    \centering \ulqdaTable{} \caption{QDA Table}
  \end{table}

  \begin{table}[h]
    \centering \ulqdaCloud{} \caption{Code Cloud}
  \end{table}
```

Figure 8: ul*q*da Visualisation Macro Usage

Four forms of visualisation are provided for by the ul*q*da package, and they are shown in Figure 8:

- `\ulqdaGraph{flat}[dot2texi-options]` — an ontology represented by a flat graph of codes;

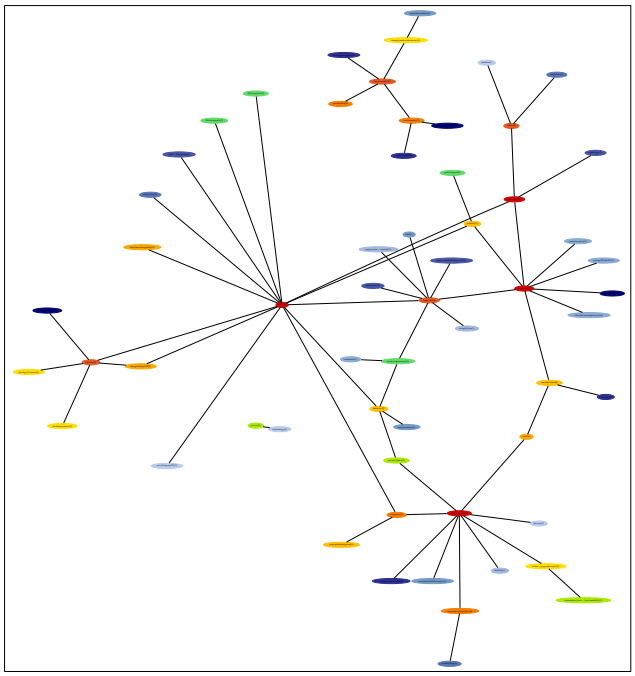

Figure 9: Visualisation of a coded Ontology

- `\ulqdaGraph{net}[dot2texi-options]` — an ontology represented by a hierarchical network of codes;
- `\ulqdaTable{}` — a flat list of codes in tabular form;
- `\ulqdaCloud{}` — a flat list of codes, 'tag-cloud' style.

[11] describes *visualisation* as 'a broad term that refers to an array of methods that are used to provide insight into data through visual representations'. Figure 9 gives an example of a GraphViz rendered visualisation of a coding ontology. The CSV output from the LaTeX parsing was converted into a set of node descriptions suitable for input into GraphViz (currently via a Perl script that is spawned from the ul*q*da package – although as luaTeX gains traction, it should be possible to migrate this directly into the package itself).

At this point, these ontologies were printed out on large sheets of paper (A3/foolscap) and were annoted by hand. These annotations formed the basis of memo writing—that is, the writing of paragraphs describing certain observed themes and theme interrelationships, and hypothesising about their rea-

son. There is still some academic slogging required to get from this point to a coherent theory that explains the phenomena under study, but we really can't expect LaTeX to do all the work. We found that getting to the point where we had visualised ontologies created automatically of significant value.

5 Biographical Tables

Our primary data collection mechanism was interview based. When writing up a theory based on a primary data source like this, sprinkling quotations from these interviews through the text helps add weight and credibility to the themes that are expounded upon in the dissertation. Due to the nature of the consent agreements we made with our interviewees, it was necessary to use pseudonyms for reasons of confidentiality.

LaTeX can come to the rescue here also, mapping from real interviewee name (which may be more convenient to use when putting the LaTeX source together) to pseudonyms for the typeset output. PDFLaTeX can easily insert hyperlinks in the PDF output from the interviewee name to a table listing a brief biography of each interviewee.

Consider the case of an interviewee 'John Smith', or JS for short. Rather than using his real name in the text, we prefer to refer to him as 'James'. We can use `\Interviewee{JS}` to typeset 'Interviewee James', or `\Interviewee*{JS}` to typeset 'James' – in either case, the output will hyperlink to `interviewee_bio_js`, which can be used as a label in an appropriate list of interviewees or table of interviewee biographies—as shown in Figure 11.

This allows the reader, when browsing the PDF on scren, to quickly jump from a typeset interview to relevant biographical details about the interviewee.

6 Conclusions

In this article, we have demonstrated that LaTeX is a most promising tool for the development of workflows in order to perform Qualitative Data Analysis. In addition, we have introduced the ul$_q$da package (available on CTAN) that contains various macros we have developed. That package included documentation of the macros, and a small test example that illustrates the basic concepts in action—

```
% From http://codeinthehole.com/tutorials/thesisfile/index.html 2009.06.16
%  "Things get a little messy now as a hack is required to ensure the
%   hyperlinks actually jump to the right place. No need to worry about
%   this code, let's just move straight on."
%
% see also http://www.tug.org/pipermail/pdftex/2002-August/002955.html
% for a better description of the problem.
%
% Putting in a blank line after hypertarget and the text does fix this,
% but upsets subsequent table formatting.  Hack is to allow it here, and to
% fix up in the table itself by  removing the line from there... Ugly but works.
\newcommand{\AnchorInterviewee}[1]{\hypertarget{interviewee_bio_#1}\\%
  {\expandafter\csname Interviewee#1\endcsname{}}}

\makeatletter
\newcommand{\Interviewee}{\@ifstar\IntervieweeStar\IntervieweeNoStar}
\newcommand{\IntervieweeNoStar}[1]{\hyperlink{interviewee_bio_#1}%
  {Interviewee~\expandafter\csname Interviewee#1\endcsname{}}}
\newcommand{\IntervieweeStar}[1]{\hyperlink{interviewee_bio_#1}%
  {\expandafter\csname Interviewee#1\endcsname{}}}
\makeatother

\newcommand{\IntervieweeJS}{James}
% etc.
```

Figure 10: LaTeX Macros for Interviewees

IG: Do you think the social aspect of face to face is important for the project? ...
Interviewee XYZ: ...A cup of coffee is really important because then what happens is that you get a real perspective. My general experience of having a functional group in one site, while I was in the other one, working for you and using video conferencing, if you really wanted to get things done you had to jump on a plane and fly over, there was nothing that could make up for sitting in a room with people to both get across the urgency and to ensure that communication among the team took place to address any of the issues...

geographicalsocial, geographicalface-to-face, geographicaltelecoms

Interviewee	Experience
	...
Interviewee XYZ:	Engineering Director (Software) at Intellectual Property Company Senior Staff Engineer at Fabless Semiconductor Company PhD. in Electronics
Interviewee ABC:	Senior Staff Engineer at an Intellectual Property Company (10 years) M.Eng. in Computer Engineering
	...

Figure 11: Coded Interviews link to Interviewee Biographies

although to gain maximum benefit from it, a basic familiarity with QDA and with grounded theory would be beneficial.

We found in practice that processing of QDA-coded sections of text using our LaTeX macros does increase the time taken for the overall LaTeX typesetting run, and so it does make sense to organise your workflow to cache where possible. This was especially true in the case of visualising the coded hierarchies, as per Figure 9. Kjell Magne Fauskes' online version of dot2texi.sty[3] supports generated caching of images, whereas the version in CTAN[4] currently (2010-01-20) does

3. http://www.fauskes.net/code/dot2tex/download/
4. http://www.ctan.org/tex-archive/macros/latex/contrib/dot2texi/

not. This cache speeds up things significantly, as the GraphViz dot to Ti*k*Z/PGF conversion can take considerable time.

6.1 Possible Enhancements

As luaTEX becomes more commonplace for this kind of research, it may serve as a more suitable engine for QDA workflow automation — removing the need for an external Perl helper script and potentially speeding up some of the processing that is currently done (rather clunkily) via LATEX. For example, although TEX is a Turing-complete language, it doesn't have good abstract data type macros, and doesn't have comprehensive file I/O support (for example, no append).

We are certainly keen to receive suggestions for new features or improvements that could be made to the package.

7 Acknowledgements

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The image of manual coding is courtesy of
http://www.flickr.com/photos/jeanbaptisteparis/1041028095/sizes/o/#cc_license.

8 Authors' Biography

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5. http://www.lero.ie/

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10 Appendix

Figure 12 shows an example of the output generated through the use of `\ulqdaGraph{net}{...}`:

```
digraph codes {
overlap=scale
ratio=compress
splines=true

#
# Nodes
#
Node19a6c32cd6543441c9f5a7d4539e0435a4465c83 [label="geographical(8)", fontsize=75,color="#d40000",style=filled]
Node11a110bbef1bcc07ee6b72c48ab5c5b21afbab91 [label="risk(6)", fontsize=60,color="#d40000",style=filled]
Node0dbe529c4dfad996667815f32902cb3a2b94c94f [label="social(4)", fontsize=45,color="#e35a24",style=filled]
Nodea2cde247b653bf985a93587cb49f6784ee624876 [label="Fabless(2)", fontsize=30,color="#f67c00",style=filled]
Nodeb99f24955c90296fabf855bb4d54929a3fef70e1 [label="HW fear of risk(2)", fontsize=30,color="#f67c00",style=filled]
Node590a7e00c093739b631454471d81d81b71e093c7 [label="incidental is most important(2)", fontsize=30,color="#faa800",style=filled]
Node9fa7f61fda21f51c481ba3721c0f072e33d2abc0 [label="business model(2)", fontsize=30,color="#ffc000",style=filled]
Node925b4271c1d7533eb2d3cb2154cfec4eb06734cf [label="changeability of SW(2)", fontsize=30,color="#ffde00",style=filled]
Node60c58ad2ef34d96fae028f1039fab03dec9eb9a2 [label="communication(2)", fontsize=30,color="#ffde00",style=filled]
Nodeb141e518c599a399b7be41eb751f8b3701652e0f [label="HW bias(1)", fontsize=22.5,color="#aae900",style=filled]
Nodef90836d07f1e94806617725784c78e4e89824127 [label="mindset gap(1)", fontsize=22.5,color="#62dc68",style=filled]
Node2d5665952d74d765d3aad8ab414f96fe4dc51db9 [label="importance of face to face(1)", fontsize=22.5,color="#bbcced",style=filled]
Nodeb9a3688b2fbb6672ff80b8f5ae966ceda0908053 [label="cross-functional(1)", fontsize=22.5,color="#bbcced",style=filled]
Node8f2e7cd784967d6a79abd59093146fb1f82e336d [label="culture(1)", fontsize=22.5,color="#a3bbe0",style=filled]
Nodee141e4d99297842c281e4224078bca1e8b995691 [label="technical determinism(1)", fontsize=22.5,color="#8aaad4",style=filled]
Node11e9ba26c91a2db7452a5ef9ff7051e19b6b377a [label="schedule(1)", fontsize=22.5,color="#8aaad4",style=filled]
Nodeb27b5212ac50ce33cffd24b9841a5a83a8108ad9 [label="risk mitigation(1)", fontsize=22.5,color="#7299c7",style=filled]
Node65279e1ecf00d0d1177a5b3b458fd187a1d6135e [label="verification(1)", fontsize=22.5,color="#5676b5",style=filled]
Nodec5202d931786b95a00f51eeb98085e3f6bf75640 [label="product specification(1)", fontsize=22.5,color="#4554a3",style=filled]
Nodebd3d92295c56dd6ca534455108d979e18c993099 [label="social risk(1)", fontsize=22.5,color="#4554a3",style=filled]
Node857a3f01adebeadc2e3233e182485ad98fa4808b [label="telecoms(1)", fontsize=22.5,color="#2e3191",style=filled]
Noded16de2d0bbd9386cde684be84b1261f6ac175035 [label="market risk(1)", fontsize=22.5,color="#000472",style=filled]

#
# Connections
#
// business model!Fabless!market risk
Node9fa7f61fda21f51c481ba3721c0f072e33d2abc0->Nodea2cde247b653bf985a93587cb49f6784ee624876 [label="", w=0.4375, len=0.4375]
Nodea2cde247b653bf985a93587cb49f6784ee624876->Noded16de2d0bbd9386cde684be84b1261f6ac175035 [label="", w=0.4375, len=0.4375]
// risk!risk mitigation!Fabless
Node11a110bbef1bcc07ee6b72c48ab5c5b21afbab91->Nodeb27b5212ac50ce33cffd24b9841a5a83a8108ad9 [label="", w=0.8125, len=0.8125]
Nodeb27b5212ac50ce33cffd24b9841a5a83a8108ad9->Nodea2cde247b653bf985a93587cb49f6784ee624876 [label="", w=0.34375, len=0.34375]
// risk!verification
Node11a110bbef1bcc07ee6b72c48ab5c5b21afbab91->Node65279e1ecf00d0d1177a5b3b458fd187a1d6135e [label="", w=0.8125, len=0.8125]
// risk!product specification
Node11a110bbef1bcc07ee6b72c48ab5c5b21afbab91->Nodec5202d931786b95a00f51eeb98085e3f6bf75640 [label="", w=0.8125, len=0.8125]
// culture!mindset gap
Node8f2e7cd784967d6a79abd59093146fb1f82e336d->Nodef90836d07f1e94806617725784c78e4e89824127 [label="", w=0.34375, len=0.34375]
// geographical
// risk
// geographical
// business model
// risk
// risk!social risk
Node11a110bbef1bcc07ee6b72c48ab5c5b21afbab91->Nodebd3d92295c56dd6ca534455108d979e18c993099 [label="", w=0.8125, len=0.8125]
// schedule
// changeability of SW
// HW bias
// HW fear of risk
// HW fear of risk
// changeability of SW
// geographical
// social
// geographical
// social
// incidental is most important
// communication!telecoms
Node60c58ad2ef34d96fae028f1039fab03dec9eb9a2->Node857a3f01adebeadc2e3233e182485ad98fa4808b [label="", w=0.4375, len=0.4375]
// geographical
// social
// incidental is most important
// cross-functional
// geographical
// communication
// social
// geographical
// importance of face to face
// technical determinism
// geographical

}
```

Figure 12: Parsed input for neato