NLP for Requirements Engineering: Tasks, Techniques, Tools, and Technologies

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***Abstract*—Requirements engineering (RE) is one of the most natural language-intensive fields within the software engineering area. Therefore, several works have been developed across the years to automate the analysis of natural language artifacts that are relevant for RE, including requirements documents, but also app reviews, privacy policies, and social media content related to software products. Furthermore, the recent diffusion of game-changing natural language processing (NLP) techniques and platforms has also boosted the interest of RE researchers. However, a reference framework to provide a holistic understanding of the field of NLP for RE is currently missing. Based on the results of a recent systematic mapping study, and stemming from a previous ICSE tutorial by one of the authors, this technical briefing gives an overview of NLP for RE tasks, available techniques, supporting tools and NLP technologies. It is oriented to both researchers and practitioners, and will gently guide the audience towards a clearer view of how NLP can empower RE, providing pointers to representative works and specialised tools.**

I. Technical Briefing Proposal

a) Topic: The topic of the proposed technical briefing is natural language processing (NLP) for requirements engineering (RE) [1], [2]. This is a specialised, yet highly multi-faceted research topic that has received attention since the '90s, with seminal contributions mostly focused on generating models from requirements [3], [4]. Later, NLP has been applied to automate the typical time-consuming RE tasks, such as defect detection [5], requirements tracing [6], and categorization [7]. With the emerging of novel RE-relevant formats and sources, such as user stories [8], but also app reviews [9] and privacy policies [10], the field has expanded its scope of application to tackle issues specifically related to these types of artifacts. In parallel, NLP, and artificial intelligence techniques in general, have seen a tremendous breakthrough in the last decade after the development of game-changing technologies generally classified under the umbrella of *deep learning* [11]. These two trends have created further synergies between NLP and RE, and a mapping study was performed by the proponents of this technical briefing to provide a holistic understanding of the field [2]. The study analyses 404 papers on the topic, and provides statistics on multiple relevant facets (e.g., documents used, techniques, NLP tools, resources), giving not only a report on the state-of-the-art, but also a conceptual reference framework to make sense of current research in the field, and its possible evolution.

This technical briefing stems from the results of the mapping study, and aims to provide a blueprint of the landscape of NLP for RE, in terms of (1) *tasks* that can be automated (2) NLP-based *techniques* that are available to support the tasks (3) *tools* that support the techniques, and (4) established and novel NLP technologies that are relevant for RE and can further advance the field. In particular, part of the talk will present the concept of *transfer learning*, and the BERT language model [12]. Transfer learning is based on reusing pre-trained models to new and unseen problems, and this can be particularly useful in RE, where datasets to train models are particularly scarce [1]. The specific merit of BERT is its versatility to be used in different NLP downstream tasks such as text classification, question-answering and named-entity recognition, which are useful to several RE tasks as reported in the mapping study [2]. For example, in the case of requirements classification, using a pre-trained model such as BERT and fine-tuning it with labelled requirements generates promising results, as shown by recent work [13], [14].

The topic of NLP for RE is particularly relevant and timely, given the recent NLP developments not yet absorbed by the RE community [2]. It is also the right time for technology transfer, as it has been observed that only 16% of companies use some form of automation in requirements analysis [15], and only 7% of the works retrieved in the systematic mapping study concern industrial applications, while a plethora of different solution proposals is available (67% of the studies) [2].

b) Format: The technical briefing consists of 90 minutes of presentation, and is divided into three main parts. The first part is dedicated to provide an overview of the different RE tasks that can be supported by NLP techniques, such as traceability, defect detection, requirements classification, etc. This is followed by an overview of the results of the mapping study, and representative contributions are presented to illustrate available techniques and tools developed to support each RE task. Particular relevance will be given to point to enabling technologies and platforms from the NLP field. The mapping study has identified a clear lack of adoption of cutting-edge NLP technologies in RE. Therefore, to trigger interest and open to further development, the final slot will focus on the presentation of one specific NLP technique that we consider of potential interest for both RE and software engineering (SE) practitioners, namely the BERT model [12].

c) Interest for the Community: The first author provided a technical briefing at ICSE'18 on the topic [16], and the presentation received high interest from the audience—20 to 30 participants were present. While the previous briefing was mostly focused on consolidated NLP technologies that could be used in daily RE practice, this new one has the objective of giving a holistic view of the field, also based on empirical data from the mapping study, and considering recent developments. This can be of interest to researchers willing to address current gaps, but also to practitioners who want to know where the field is now, what are available tools, and who are the reference experts to involve in research-industry collaborations. Furthermore, we believe that the final slot, dedicated to the presentation of BERT, can raise the interest of the whole SE community, as NLP has seen several applications also in software testing (see, e.g., the recent mapping study from Garousi et al. [17]), and maintenance [18], [19]. Overall, our goal is also to raise awareness about current research on NLP for RE within the SE community, suggest NLP-centered synergies, and pave the way for more integration between different SE perspectives.

II. Biographies

Alessio Ferrari is research scientist at CNR-ISTI (Consiglio Nazionale delle Ricerche - Istituto di Scienza e Tecnologia dell'Informazione was "A. Faedo", Pisa, Italy - http://www.isti.cnr.it), where he works since 2011. He received his Ph. D. in Computer Engineering from the University of Florence, Italy, in 2011. His current research interests are applications of NLP techniques to RE, requirements elicitation, and RE teaching. In particular, his main focus is natural language ambiguity detection and mistakes identification in requirements elicitation interviews and requirements documents. Ferrari participated in several European Projects, including Learn PAd, ASTRail, and DESIRA. He is author of more than 70 papers in relevant conferences (RE, ICSE) and journals (REJ, EMSE, IEEE Software). He served in the PC of ICSE, IEEE RE, REFSQ, he has been co-organiser of two editions of the NLP4RE workshop, and local organiser of REFSQ 2020.

Liping Zhao is Associate Professor in Department of Computer Science, the University of Manchester. Her current research focuses on using NLP and machine learning to support RE. From 2004 to 2014 she had been in collaboration with IBM on Pattern Language for the Design and Development E-business Applications and received three IBM Faculty Awards (2004, 2005, and 2008) for her contributions. From 2007 to 2012, she co-founded and led a multidisciplinary academic network in the UK on service science (SSMEnetUK), funded by the UK Research Council, BT, HP, and IBM. She is an Associate Editor for Requirements Engineering (Springer) and Expert Systems (Wiley). She has served on numerous conferences and workshops, and has been co-organiser of IEEE International Workshops on Requirements Patterns, co-located with RE Conference (from 2012 to 2016) and International Workshop on Advances and Applications of Problem Orientation (IWAAPO), co-located with ICSE (2010).

Waad Alhoshan is an Assistant Professor in the Department of Computer Science, IMSIU. She received her PhD degree in Computer Science in 2020 from the University of Manchester, where she studied corpus-based and language modeling techniques to investigate approaches for detecting semantic relationships between software requirements. During her PhD, Waad published several papers in peer-reviewed conferences such as LREC, RE and ESEM. Currently, she is cooperating on multiple research projects on designing NLP-based systems to support software in Arabic and English languages. One of these projects is a collaboration project between IMSIU and the Saudi Authority for Intellectual Property (SAIP) to design AI-driven systems for processing legal documents.

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