ICT with Industry
Workshop report

Lorentz Center, November 27 – December 1, 2017

Introduction

The economic priority areas (topsectorenbeleid) set by the Dutch government encourage academic researchers to actively collaborate with the private and public sector by launching targeted activities. Since 2013, NWO (and STW) are collaborating with the research schools ASCI, IPA and SIKS in the organization of the ICT with Industry workshop. The main aim of the workshop is to increase the collaboration between science and industry. The workshop strives for direct and rapid interaction between ICT researchers and industrial partners. It has the following objectives:

- To stimulate contact between ICT research and industrial R&D, by identifying and analyzing challenging problems and emerging technologies in multidisciplinary teams.
- To obtain creative solutions for industrial problems and to find new approaches that could lead to such solutions.
- To give insight into the wide range of possibilities ICT research offers (primarily to industry, but also to the general public), and thereby enable accelerated innovation.
- To enrich the PhD students' and postdocs' experience in collaborating with industry.

For companies, the workshop offers one week to collaborate with a team of dedicated researchers from various ICT-disciplines with the aim to tackle the problems in the proposed case study. The goal is to come to a practical solution or new horizons with new insights, e.g. spin-offs. For researchers, the workshop offers a week to explore their research ideas in collaboration with your company partners. They have a team of dedicated researchers from a various ICT-disciplines to work with. The goal is to come to concrete ideas which can be used for e.g. scientific paper, funding proposal to be submitted to NWO or Horizon 2020.

Organization

We solicited case studies by means of a Call for Case Studies, directed at potential industrial submitters as well as the scientific community. Every case study must identify one or more scientific challenges; furthermore, every case study proposal must have a clear industrial component, and be backed by one or more committed industrial parties. Cases were collected in two ways:

- The call for cases is broadcast through mailing lists from NWO, the research schools ASCI, IPA, and SIKS, and through social media. It was also be published at scientific events, e.g. ICT.OPEN2016.
- Each of the organizing committee members personally contacted individuals from his or her network in industry and government, NGOs, etc.

The organizing committee assessed the submitted case studies based on the following criteria:

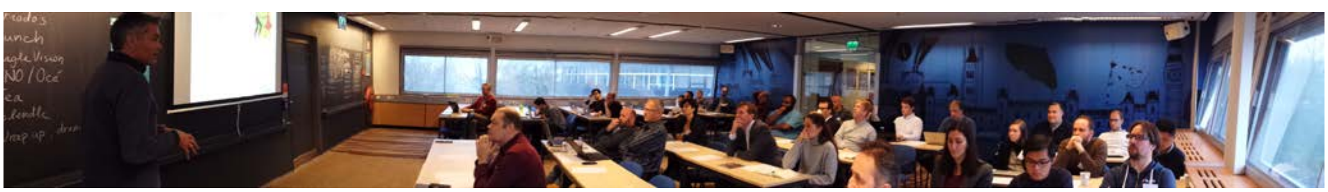
- Scientific relevance/challenge: is there a scientifically interesting challenge involved, particularly from an ICT point of view?
- Urgency: is a solution to the challenge urgently needed?
- Feasibility: is it likely that a solution or significant steps towards a solution to the challenge can be obtained within the timeframe of one week?
- Commitment: can the industrial parties commit to their involvement as stipulated below?

After a review of each proposal by the organizing committee, each case proposal was assigned to one organizing committee member for contacting the industrial applicant to fine-tuning the case proposal.

Once the cases were collected and assessed, one academic team leader per case was selected, based on the match of knowledge and expertise with the scientific relevance of the case proposal, the willingness and capability to understand the needs and questions of the case owner, and the commitment to attend the workshop the entire week. The roles of the academic leader are the following:

- Helping to come to a clear description of the problem, objectives, and targeted results is available.
- Recruiting workshop participants from her/his own academic network.
- Organizing a meeting between (some of the) participants and case owner prior to the workshop to initiate "expectation management".
- Supervising the activities and progress of the case during the workshop. The team leader is expected to be present at the Lorentz Center during the whole week.

The workshop itself was held in the Lorentz Center, location Oort, November 27 till December 1, 2017. It started with a presentation of the cases to all participants. Then the four teams worked in parallel on their own case during the week. At the end of each day there was a short plenary progress report, and at the beginning of each next day there was as short start-up meeting per group. On the last day, the results were presented in a plenary session to all participants and additional interested people from industry and the press.



Cases

This year, we had four case studies:

- Triodos Bank: An eco-system for a multi-company blockchain with an alternative currency.
- Blendle: Personalized news selection.
- TNO-ESI and Océ: Architecting support using system architecture knowledge graphs and expert systems.
- ICT for Brain, Body & Behavior (Eagle Vision): Deep learning for visual verification.

A total of 40 participants from industry and academia were working on these four cases. The following chapters present the problem that was investigated and the progress that was made in solving these cases.

Organizing Committee

The organizing committee consisted of the following members:

Dr. Claudia Hauff (TUD)
Prof. Dr. Patricia Lago (VU)
Dr. Ana Maria Oprescu (UvA)
Prof. Dr. Arend Rensink (UT) – chair
Prof. Dr. Remco Veltkamp (UU)

We thank NWO and the Lorentz Center for supporting the workshop financially and organizationally.

January 2018

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TRIODOS Bank: An eco-system for a multi-company blockchain with a complementary currency

Participants: Anna Bon, Sven Duyx (company representative), Jaap Gordijn (academic leader), Dan Ionita, Pieter Kwantes, Marc Makkes, Vincent Meeuwsen (company representative), Jan Rellermeyer, Roel Wieringa

Context and problem

United economy on blockchain

The Dutch initiative United Economy (started in 2015) consists of a network of companies that envision a greener, more social economy with its own rules and its own currency: the United. The companies deliver goods and services amongst each other based on real economic value and they pay the invoices in Uniteds. By keeping the Uniteds in their own circle it enables them to create green impact repeatedly.

This initiative is concerned with the real economic value produced by companies, exchanged via the United ('supplier's credit'). The United can only be used -by design- as a medium of exchange because no party can speculate with Uniteds. Members cannot earn interest on savings of Uniteds. The United is 1:1 related to the Euro. All tax rules and general bookkeeping rules apply. Tax can only be paid in Euro's. A membership mechanism exists. Only companies that are "green" or "green enough" can join and members may have to periodically report their satisfaction of some green criteria.

The Uniteds can be considered as a complementary currency next to the Euro, but is only valid in the group of participating companies, which we further call a community.

The United Economy initiative is organized by means of a co-operative and foundation in which participants are (possibly indirectly) represented.

The United Economy co-operative manages the operations to run the United Economy: eg. Administration, marketing and sales, arranging memberships, revoking memberships, arranging the possibility to run transactions in Uniteds, granting loans in Uniteds, handling possible bankruptcy of members related to their loans etc. Also, they organize events where people and organisations meet up. The United Economy co-operative members decide on the plans and financials, they mandate the co-operative to execute those plans and they provide funding through, for example, their membership.

The United Economy Foundation safeguards the ground rules of the concept. Any decision by the co-operative that impacts these specific rules needs an advice and decisive vote from the United Economy Foundation. The United Economy Foundation also holds the coverage fund and the guarantee fund. These funds are the mechanisms that ensure the value of the United related to the Euro, mainly based on the loans provided.

Currently, the United Economy initiative is supported by a centralized information system that keeps track of the transactions and balances of the participants. In fact, the same system supports other complementary currencies.

The United Economy initiative is an example of a more general phenomenon, namely the wish to give direction to where money goes and what impact it creates. Some other examples of this kind of communities are the Sardex network (Italy) and WIR Bank (Switzerland).

Blockchain technology

Triodos Bank (Zeist, The Netherlands, one of the members of United Economy) and the University of Twente executed a pilot in November 2016, showing the feasibility of using the Hyperledger blockchain technology for keeping United transactions in decentralized way, thereby potentially removing the centralized information system. The result of this pilot motivates a more in-depth exploration of how to apply the blockchain technology and its underlying philosophy to the United Economy initiative.

Problem statement

How to apply the blockchain technology philosophy such that communities (for example the United Economy), with their own complementary currency can benefit from it. Two important aspects of the blockchain philosophy to consider are (1) increasing transparency of the information in the network, more specifically the transactions, and (2) removal of the middlemen.

Research approach

We execute the following research approach to solve the above problem:

1. Analysis of the existing United Economy goals and its stakeholders as an example of similar, communities with their own complementary currencies.
2. Elicitation of functional and non-functional requirements of, communities with their own complementary currency with blockchain technology as their technology platform.
3. Creation of a solution space with a number of solutions, which all use blockchain technology.
4. Scoring the solution space using the requirements as identified in step 2.
5. Selection of solution to focus on.
6. Selection of the most optimal blockchain technology for the selected solution using the requirements elicited in step 2.
7. Design of a revised business model for alternative, community oriented complementary currencies using blockchain.

Results

Analysis of the United Economy initiative goals and its stakeholders

Overall goals:
The network of entrepreneurs that together builds towards an honest, social and green economy, with the use of its own 'money' the United. By creating (more) sustainable impact. Based on membership to ensure e.g. only members that align with the United Economy goals and their own sustainable policies.

Stakeholders:

- Partners (can trade), they get an initial loan in Uniteds
- Members (can trade), they do not get an initial loan in Uniteds
- Network members (cannot trade)
- (Consumers: private person who wants to become a member) – not yet part of the initiative, possibly in a later stage
- United Economy co-operative
- United Economy foundation
- Suppliers to the co-operative and (possible) role:
    - Triodos Bank (credit check)

- Software provider
- Insurance (liability of management) o MRO suppliers
- Legal advice

- Tax authority

Elicitation of functional and non-functional requirements of the United Economy with blockchain technology as platform

Functional requirements:

1. become a member
2. revoke a member
3. issue complementary currency
4. enabling transactions with the complementary currency
5. grant and revoke access of members to the platform (and therefore to e.g. to possibility to pay for goods or services)
6. regulate the system (e.g. changing the rules for credit, issue of currency, etc.)

Non-functional requirements:

1. the system should be trustworthy to the stakeholders
2. risk of defaulting (e.g. bankruptcy) should be covered
3. reach consensus about the transaction truth and regulation changes in environmentally friendly way (lowest Carbon print)
4. scale up the number of members, but not necessarily the number of blockchain nodes
5. scale up the number of transactions
6. run the solution locally, e.g. not exclusively as a software-as-a-service

Creation of a solution space with a number of solutions which all use blockchain technology

We envision three different solutions:

1. Centralized solution: Using the blockchain as a technology only to replace the current centralized information system. The control of all current tasks of the centralized co- operative and foundation as for example in the United Economy remain unchanged.
2. Decentralized solution: The control of all tasks of the co-operative and foundation are now distributed over all the nodes in the network.
3. Hybrid solution: Granting access and revoking access to members and the guarantee fund and coverage fund are centralized. It is possible to decentralize both functions (see solution 2), but they can be easier realized by a central authority. Also, this solution can considered as an intermediate step to arrive from the current centralized solution to a fully decentralized solution.

Scoring the solution space using the requirements

1. Centralized solution: All tasks are performed under direct control of the co-operative and foundation; nodes are only used for computational purposes.
   a. Advantages: increased redundancy of the currently centralized IT

   b. Disadvantages: increased costs, overhead, low scalability, centralized, unequally divided power
2. Decentralized solution: All tasks of the co-operative and foundation are controlled and performed by the network, in practice by all the nodes.
   a. Advantages: increased redundancy of IT, flexibility, rapid expansion, agility, forking (easy formation of sub communities), removal of middlemen and spreading of power equally over the network
   b. Disadvantages: devaluation, fraud, malicious members, brand abuse (although for most of these mitigations can be thought of)
3. Hybrid solution: Granting access and revoking access to members and the guarantee and coverage are under control of a central authority; the rest is under control of all nodes, collectively called the network.
   a. Advantages: increased redundancy of IT, flexibility, rapid expansion, agility, forking
   b. Disadvantages: distributed risk, centralized power (co-operative, foundation)

Selection of solution to focus on
We focus on the fully decentralized solution because this is the most innovative one. Moreover, we claim that the hybrid solution is just a variant of the decentralized solution. Finally, the centralized solution does not follow the philosophy of the blockchain and does not really bring anything extra. It only serves as a (costly) distributed implementation platform. This is according to Gartner is the number 1 mistake in current blockchain implementations.

Selection of the most optimal blockchain technology for the selected solution using the requirements
The blockchain technology for the fully decentralised variant that satisfies most requirements is Hyperledger with the consensus mechanism Proof of Elapsed Time (PoET).

Design of a new business model for the United Economy using blockchain
We have designed a draft e^3value model that supports a fully decentralized business model and includes the financial consequences of the use of Hyperledger. The business model shows how the United is created, exchanged, as well as how defaulting is treated. Moreover, it shows how Hyperledger nodes are compensated for their services to the network. The model needs further detailing.

Future work

The following steps should be undertaken:

1. Completion of the e^3value model.
2. Quantification of the e^3value m
3. Scenario-based financial sensitivity analysis of the e^3value model.
4. Executable process specification, which can be considered as an implementation of the e^3value model.
5. Stochastic simulation of the executable process of the decentralized solution, using multiple change scenarios (e.g. growth of number of members, growth of number of transactions, significant number of defaulting, etc).
6. Proof-of-concept using Hyperledger (PoET).
7. Field tests.

Blendle: Personalized news selection

Participants: Hans Bos, Dror Guldin, Claudia Hauff, Daan Odijk (industry representative), Reza Aditya Permadi, Sihang Qiu, Emily Sullivan Mumm, Nava Tintarev (academic leader).

Context and problem

We looked into the challenges of filter bubbles and recommendation bias, aiming to provide a balanced, diverse, and relevant selection of news clearly that helps with discovering quality journalism.

A new generation is growing up that do not get their news from a newspaper. According to a study from 2016 indicates that social media has overtaken television as young people's main source of news. These readers have a hard time finding quality; for example, Twitter offers a noisy stream of information, Facebook does not optimise for quality, but for clicks and is increasingly flooded with fake news. In some cases this means that users are unaware of opposing points of view, so called `filter bubbles', leading to informational blindspots, and potentially more polarized opinions. Such filter bubbles are partially due to recommender systems which through personalization automatically select and filter content for users.

Recommender systems support people in making decisions about what to consume next, they propose and evaluate options while involving their human users in the decision-making process. Recommender systems also shape our opinions by automatically selecting and ranking information for us in online social networks such as Twitter and Facebook. These technologies have in some cases been found to decrease exposure to more diverse points of view, but they also have the potential to increase content diversity. One neglected aspect of the study is how recommender systems can help users manage their information diet .

In this hands-on workshop, we took on the challenges of filter bubbles and recommendation bias by developing methods for complete and personal news selection. With datasets of news articles and associated meta-data from Blendle, two recommender experts and the participants, we developed a better way of finding news.

Research approach

Our work is based on the assumption that recommender systems can select content that is both relevant and diverse, but that we need to improve our methods for selecting diverse content. The motivating use case is a user who is focused on certain topics in a given time frame, unaware of related topics which are perceived as important by other groups. The user goes to the system which automatically lists topics that are highly relevant that week (Figure 1).

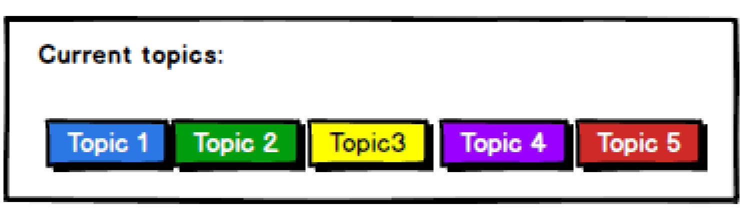
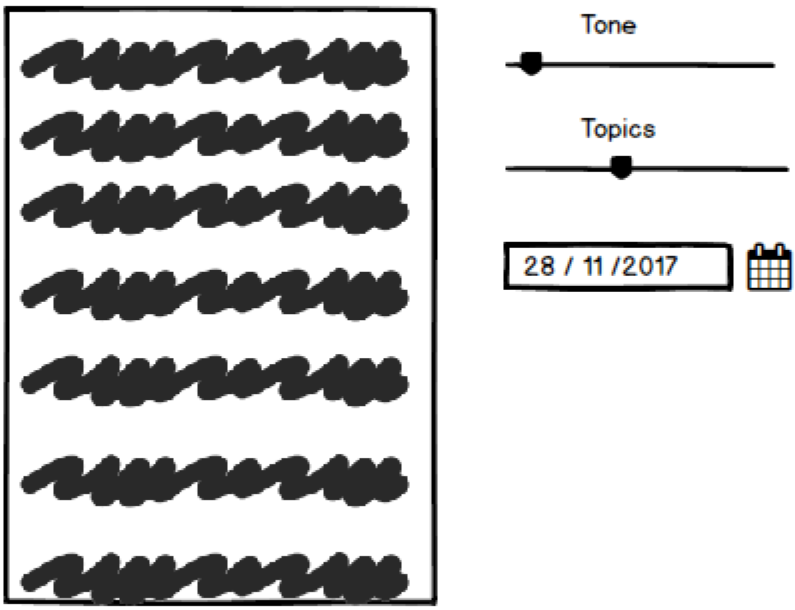


Figure 1: Automated topic suggestion.

This use case relates to the idea of *agenda-setting* in political communication. Agenda-setting is the role of news media which relates to its power "to focus public attention on a few key public issues". Thus, "readers and viewers learn how much importance to attach to a topic on the basis of the emphasis placed on it in the news". When a user selects on of the current topics, the system can suggest recommendations that are representative of a diversity of view-points, resulting in a wider *framing*. The



user also has some controls to modify the diversity in the list of recommendations.

Figure 2: Diversified list of articles, with user controls.

To solve enable this use-case we needed to answer a number of research questions, Figure 3 operationalizes the workflow of the system in a more formal way.

- Which item features help us represent diversity in a way that reflect a number of viewpoints on the same topic?
- Which way should we combine these into a distance function?
- How do we translate the distance function to a ranked list, or which ranking function would be suitable to use?
- What is “optimal” diversity or coverage?

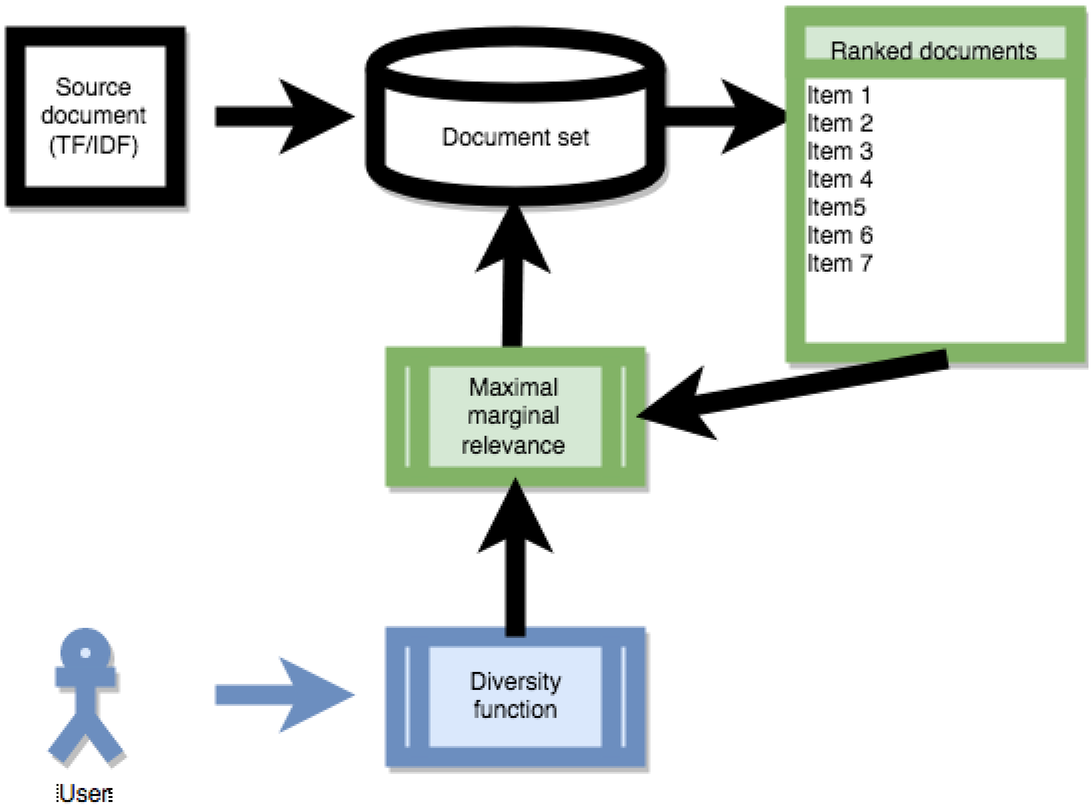


Figure 3: System workflow

Results

Building on the LIWC tool and Blendle's rich item metadata we identified a number of candidate features to aid diversification. We shortlisted them into a shorter list of features that are highly distributed and discriminating. These features were studied in several test corpora of different sizes and on different topics. We then combined the features as a weighted average into a single distance measure.

The combination was evaluated offline in a gridsearch in terms of their ability to diversity topics in terms of source and channel coverage. Our engineered weighting of features outperformed this automated maximum, as it was more coarse grained. However, the performance relative weightings are comparable.

This does not give us an indication of whether the "optimal parameters" were also optimal from a user perspective. To address this, we also designed several user studies to evaluate user acceptance of items in diversified lists.

The result of the workshop was BOA (Blendle Optimised A-list), an end-to-end system incorporating all the components above, including a user interface suitable for experimentation with end-users (see Figure 4). The LIWC tool and parameters were useful for Blendle and can be directly applied with impact in industry.

Future work

We plan to continue this work on a number of tracks including the fine tuning of the definition of some of the diversification features, and conducting more of the designed experiments. There are several mechanisms for collaboration that would interesting for us to pursue such as joint internships, MSc projects, and an application to NWO grant Industrial Doctorates.

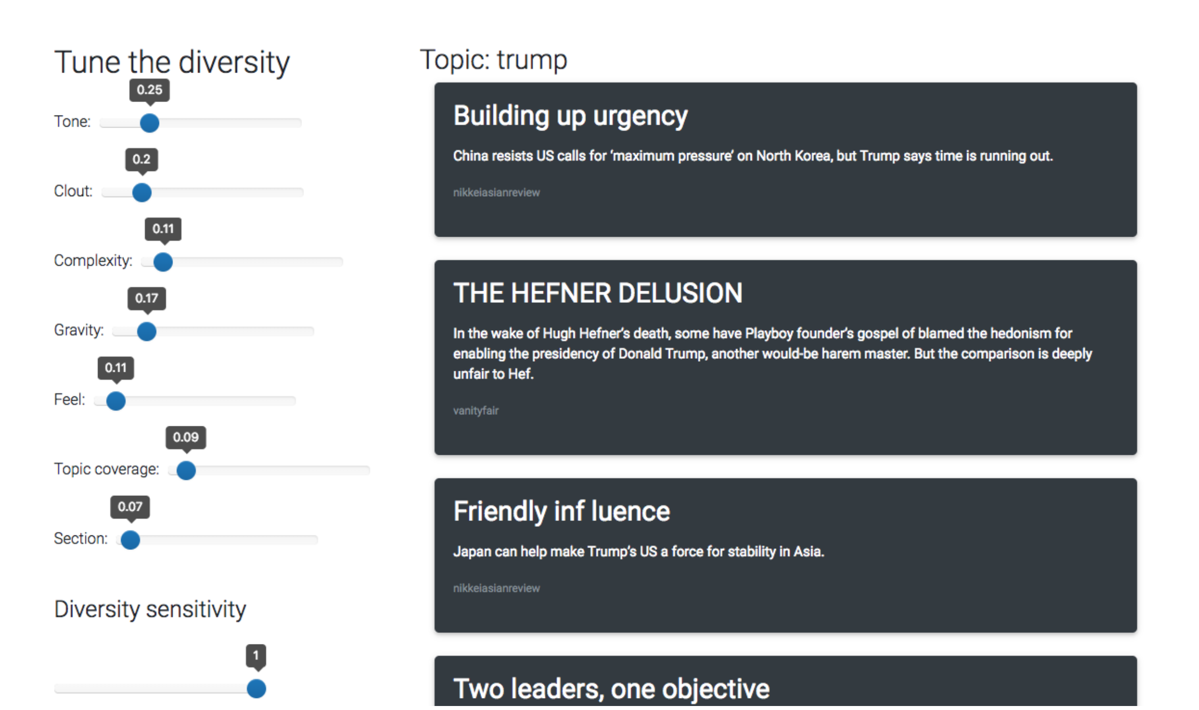


Figure 4: Screenshot of the complete system (BOA) and resulting headlines.

TNO ESI and Océ: Architecting support using knowledge graphs and expert systems

Participants: Richard Doornbos (industry representative), Paolo di Francesco, Klaas Andries de Graaf (academic leader), Ana-Maria Oprescu, Alexander Serebrenik (academic leader), Wouter Tabingh Suermondt, Roberto Verdecchia

Context and problem

The complexity in high-tech systems is increasing rapidly, therefore development of these systems is becoming a huge challenge. In particular, development of those systems is an inherently multi-disciplinary multi-stakeholder endeavour putting increasingly high demands on system architects. To address these demands TNO-ESI has advocated *knowledge graphs* (Fig. 1) as means of supporting the decision making through externalisation of shared knowledge of the system architects and stakeholders. Application of the knowledge graphs in the industry is however challenged by the high costs associated with creating them as well as insufficient clarity on return on investment for system architects. During the ICT with Industry workshop participants have focused on addressing those challenges.

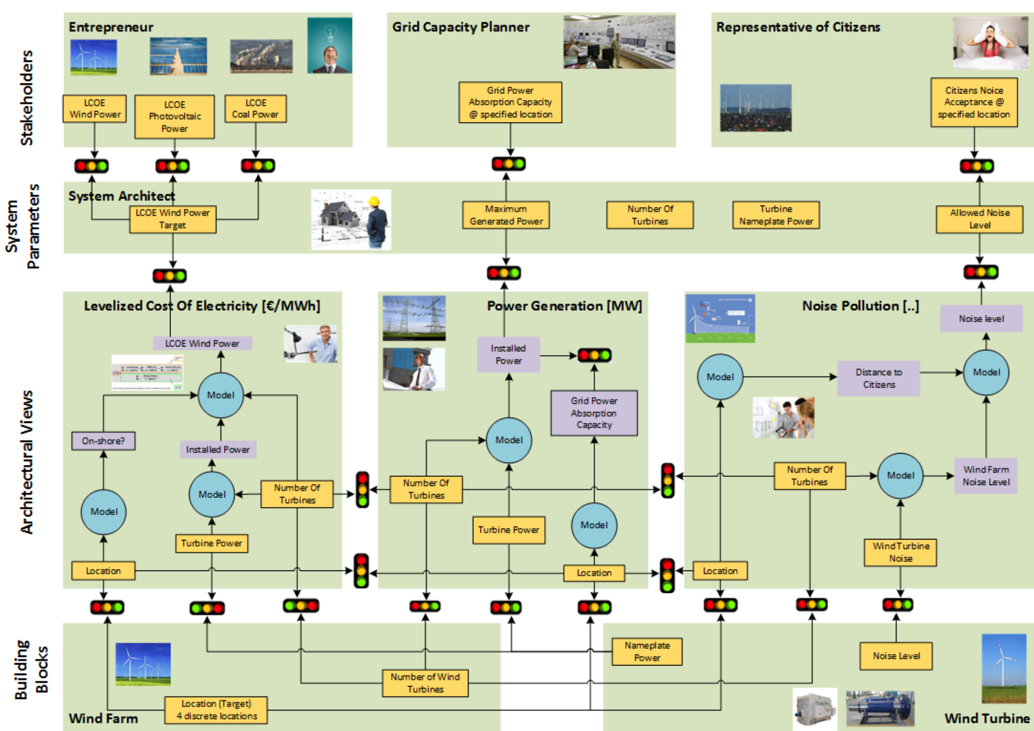


Figure 1 Knowledge graph of the windmill case

Research approach

Knowledge graph

The knowledge graph consists of responsibility domains such as shown in the Wind Farm example (Figure 1). Each of these domains involve multiple variables and relations between them. The unique feature of the knowledge graph are the *semaphores*, representing shared concerns of different domain owners or interfaces between different responsibility domains. Semaphores reflect constraints over one or more variables: the semaphore turns red when the constraint is violated (represented as traffic lights in Figure 1). For example, all stakeholders of the windmill case should agree on the location of the windmill (with the location preference of different stakeholders being variables involved).

Constructing knowledge graphs

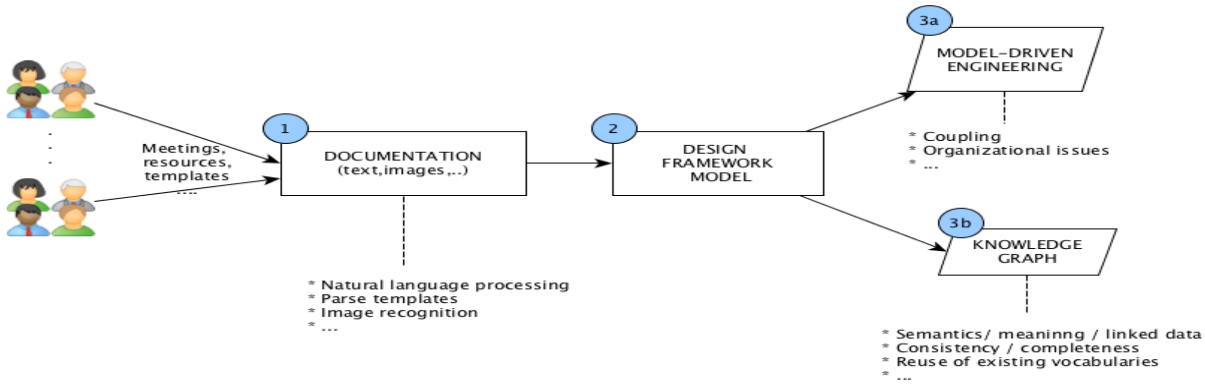


Figure 2 The process of creating a knowledge graph

As identified by TNO one of the main challenges related to adoption of the knowledge graph in the industry pertains to the effort required to construct it (see Figure 2). Indeed, architectural knowledge is often tacit and externalisation of such tacit knowledge is an important step in creation of knowledge. We propose two main lines of improving the knowledge graph construction: improving the organisation of the construction process, and automation of individual steps during this process. Improved organisation of the knowledge graph construction process can facilitate automation of the individual follow up steps, e.g., automated information extraction can benefit from standardised templates for meeting minutes and automated analysis of audio recordings---from predefined statements indicating beginning/end of the discussion phase/topic. In terms of automation of the information extraction process multiple techniques are readily available dependent on the information source: e.g., automatic document summarisation/multi-document summarisation techniques are available for textual document, while multiple research papers and patents propose summarisation of audio recordings. Applicability of these techniques to architecture information extraction should be evaluated in the follow-up study.

> In the TNO-Océ case the architects represent informal models as box-and-arrows schemes on an A3 paper. Restriction of the page size forces architects to focus on the principal elements of the solution and facilitates communication between them and the stakeholders. The box-and-arrows schemes are Microsoft Visio documents and as such can be stored as XML files amenable for further automatic processing.

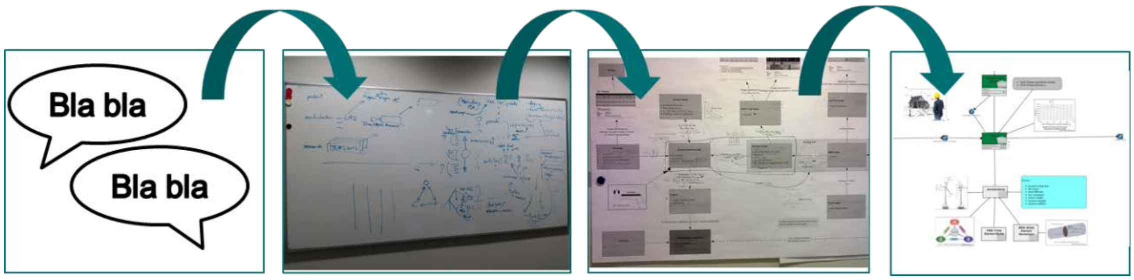


Figure 3 Early architecting process: conversations, informal modeling, A3 architecture models and knowledge graphs

Using the knowledge graphs

The knowledge graph can be used as a basis for several metrics/analyses that in their turn can be used to guide the discussions/prioritise architectural decisions. For instance, using genetic algorithms one can explore the design space and aim at finding variable assignment ensuring that all semaphores are green (all constraints are satisfied); the number of responsibility domains hosting incoming arrows per semaphore can be seen as a complexity metrics reflecting architectural hotspots; comparison of the knowledge graph with the organisational structure of the company or ecosystem of companies provides means of detecting socio-technical (in)congruence and assessing whether the responsibilities have been appropriately separated.

Most elements of the current knowledge graph constructed in the Design Framework software of TNO-ESI are of a basic 'block' type. This gives a lot of freedom in modelling different domains, process, and systems. The blocks in the DF software can be assigned labels, to make their meaning and purpose more explicit, but they do not belong to a well-defined class hierarchy and semantic relationships defined in an ontology (domain model). An ontology would improve the primary goals of the DF software, namely, communication and documentation, as it makes the input, usage, and output of the DF software more explicit and understandable by providing a common reference and understanding of the meaning of the elements, types of elements, and relationships between elements in a domain. Moreover, the instantiation of an ontology will result in a knowledge graph with meaning, which can be queried using SPARQL (the semantic web version of SQL), thereby answering relevant questions for intended users of the DF software (e.g., stakeholders, managers, and system architects) which, for example, need to know:

- Which requirements have been decided upon and are satisfied in a project?
- What is the rate of innovation in a project and what elements lead to the project goal?
- What is the separation of concerns and coupling between domains in a project?
- Is an architectural solution complete? What are the uncertainties or bottlenecks?

Representing knowledge in the DF software in an instantiated ontology (stored in e.g., RDF/TTL/OWL) also allows description of the same knowledge in the vocabulary ("jargon") of different disciplines, reuse of existing ontologies (e.g., specifying ISO standards), inference of new knowledge by logic and rules (e.g, via SWRL or class axioms), publishing the DF knowledge graph as linked data on the internet, and connecting to, referencing to, integrating and/or reasoning with existing linked data on the internet. Moreover, having a knowledge graph with semantics allows analysis and visualisation of the graph in more detail compared to only structural analysis (i.e., only nodes+edges without meaning).

Results

The main outcomes of this project are the identified knowledge graph design process (Fig. 2) and an ontology (domain model) to make the semantics of the knowledge graph explicit as well as the first steps towards automation of the information extraction and analyses supported by knowledge graphs. Furthermore, the discussions held during the workshop will serve as a basis for collaboration between industrial and academic partners. This collaboration can be supported through projects for PhD candidates, PDEng trainees or MSc/BSc students.

Future work

The following topics have been identified as topics for collaboration:

- Extraction of architecture-relevant information from technical documentation and stakeholder discussions: related research areas are text/audio summarisation, image processing, machine learning, software engineering.
- Design space exploration:
  - Automatic identification of variable assignments ensuring that all semaphores are green: possible techniques are genetic algorithms, constraint solving, linear optimisation.
  - Manual design space exploration with automated support: to obtain a better view on the design options, it is desirable not merely to generate a solution with all semaphores being green or all such solutions but a subset of such solutions that would be limited (to support manual inspection), representative and diverse enough (to make this inspection "complete" and "efficient").
  - Change impact analysis should provide insights in the possible impact of changes of individual variables or entire responsibility domains.
- Identification of the ontology underlying the knowledge graphs: research topics include knowledge modeling and management, model-driven software engineering.
- Socio-technical analysis of knowledge graphs and their evolution: research domains relevant to this topic are social network analysis, repository mining. The outcome of this line of work should provide the answers to the management questions and architects' questions.
- Tool support of the knowledge graph creation and use: at the moment the knowledge graph is supported by a website and is stored in an RDBMS. Richer knowledge representation, efficient data storage, improved UI and graph visualisation should be sought.

ICT for Brain, Body & Behavior (Eagle Vision): Deep learning for visual verification

Participants: Guillaume Dupont, Jan van Gemert (academic leader), Simon Haafs (industry representative), Miriam Huijser, Osman Semih Kayhan, Yancong Lin, Steve Nowee, Remco Veltkamp, Napolean Yeshwanth

Context and problem

Industrial problem. The workshop case involved automatically detecting small damages in the form of dents and scratches on images of baby food cans, while not rejecting cans where the accidental scene recording causes highlights, shading, shadows, etc. The company involved (Eagle Vision) currently has a system that is based on manually defined image processing operations. Their question is how much a machine learning approach could alleviate the manual operations. With machine learning the 'programming' is done by example. The system is given a training set of examples of the input and the expected output. The task is to automatically predict the output on unseen images. Using machine learning would circumvent the difficult trial-and-error of manual image processing operations by automatically learning them.

Scratch

Dent

Nothing wrong

Academic perspective. The state of the art of image recognition has significantly increased recently with the rise of deep learning. Current deep learning systems[1] give excellent results on classifying thousands of classes of objects, such as man-made objects such as cars, airplanes, chairs but also including fine-grained classes such as 200 different sub-species of dogs. Similar good results are obtained for detecting where an object is (object localization[2]), and for assigning a label to each pixel (semantic segmentation[3]). The academic viewpoint in this case is that it is not interesting to detect the object itself --we already know the object that will be present-- yet we want to visually verify the quality of the object. The difficulty is that there are a huge amount of appearance differences between all possible

1 Huang G, Liu Z, Weinberger KQ, van der Maaten L. Densely connected convolutional networks. In computer vision and pattern recognition 2017 Jul 1 (Vol. 1, No. 2, p. 3).

2 Lin TY, Goyal P, Girshick R, He K, Dollar P. Focal Loss for Dense Object Detection. In International Conference on Computer Vision 2017 (pp. 2980-2988).

3 Shelhamer E, Long J, Darrell T. Fully Convolutional Networks for Semantic Segmentation. IEEE Transactions on Pattern Analysis and Machine Intelligence. 2017 Apr 1;39(4):640-51.

scratches/dents, which in turn can occur at various locations in the image. There is, however, not much training data available for all possible damages, since damages do not occur frequently. These settings make the case interesting from an academic perspective.

Approach

We split our team of 6 people into three groups of two persons each. The three groups worked on the following topics:

A. Supervised learning. The standard machine learning approach is learning from labeled examples. Team A explores the effect of the limited amount of example damages
B. Synthetic generation of negative examples. Deep learning thrives on huge amounts of data. When such data is not available, current methods [REF] aim to add synthetic data by generating new images. Team B explores this direction for generating scratches/dents to be used as negative examples in supervised learning.
C. Anomaly detection. Given the huge appearance and location variation of all possible dents/scratch damages, a method that does not need damaged examples and can only uses the undamaged can images is valuable. Team C explored such an approach.

Results

Results team A: Supervised learning. The dataset contained 144,000 good images, and 2,360 images of bad cans. The source came from 6 cameras, so they first annotated the exact image of the damaged can (1 out of 6). A standard deep net (VGG16) is trained on a balanced subset of the dataset. The network got 65.54% accuracy, with a False Acceptance of 10.31% and False Rejection of 24.15%. These inital results are not good enough in an industrial setting. More images of damaged cans would improve results.

Results team B: Synthetic generation of damages. The team investigated generating synthetic scratches and synthetic dents. Results are shown below.

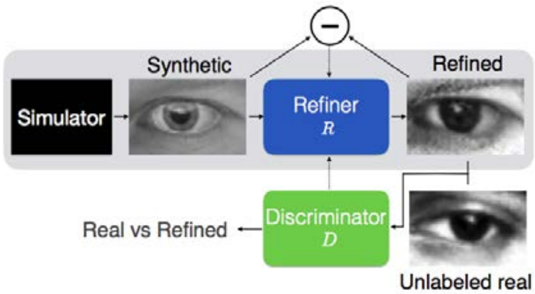
Synthetic scratches

Synthetic dents

Note that these synthetic images deviate from realistic scratches and dents. Recent work[4] has offered to learn a "refiner" network, that aims to make synthetic images similar to realistic images by fooling a "discriminator" such that synthetic and real images cannot be discriminated. See figure below (left).

4 Shrivastava A, Pfister T, Tuzel O, Susskind J, Wang W, Webb R. Learning from simulated and unsupervised images through adversarial training. In Computer Vision and Pattern Recognition (CVPR) 2017 Jul 1 (Vol. 3, No. 4, p. 6).

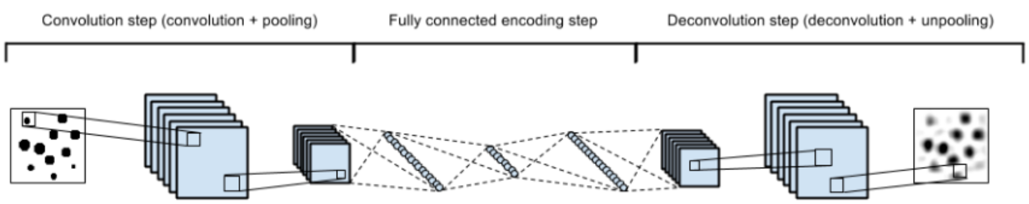
Results for cans (figure below, right) proved inconclusive. Especially the time to train these networks is in the order of several days, which proved infeasible in one week. Also, the small number of negative images made training this difficult.



Shrivastava et al. 2016

Refined can images

Results team C: Anomaly detection. The team started with an autoencoder, which can be seen as a non-linear variant of PCA for dimension reduction. It takes an input images, forces it through a bottleneck to reduce the dimensionality, and then reconstructs the image again.



An autoencoder aims to encode and reconstruct the input image

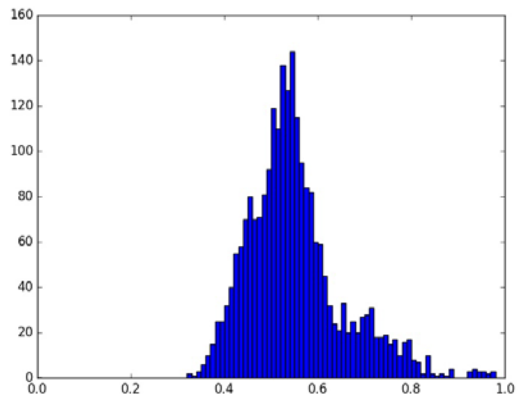
The anomaly detection is trained on positive images only. The idea is that it cannot well reconstruct images of damaged cans. Then we can measure the reconstruction error, and the hypothesis is that the reconstruction error of damaged images is higher than images it was trained on. Below are some reconstructions by the autoencoder.

Undamaged reconstruction

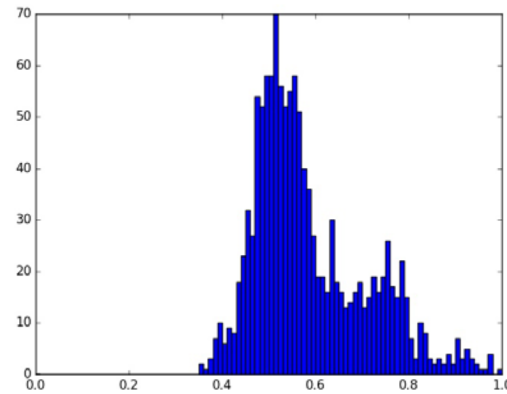
Dent reconstruction

Scratch reconstruction

The reconstruction errors, however, do not differ that much between the “good” cans and the “bad” cans. A histogram of the reconstruction MSE (Mean Square Error) is shown below.



Good cans MSE



Bad cans MSE

Future work

We have several future research directions to investigate. This may be done by a student in the future, possibly in combination with the company. We will definitely investigate closer collaboration between the university and Eagle Vision (an appointment has already been made).