

The ENRICHER Method for Human Machine Symbiotics & Smart Data

A Socially Responsible Approach to the Intelligent Augmentation of Knowledge Work

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Abstract: The systems development community is in need of a new culture, embodied in methodologies which assert human knowledge and dignity in technology development effort, especially where automation shapes working-life. Recent research, though limited, provides initial evidence to suggest industry 4.0 factory environments can satisfy the goals of human dignity and improved productivity amongst knowledge workers by developing human-centred systems. This paper looks at the unique differences between human and machine intelligences and introduces human-machine symbiotic, evolutionary development approaches. It extends the work of human centred systems in industry 4.0 settings into a very different knowledge work context: archiving cultural heritage, which has received little attention to date in IFAC.

The Insyte-Cooley Research Lab (I-CRL) using action research have sown the seeds of a new culture embodied in a systems development process called “ENRICHER” which valorises human knowledge with positive results. Extensible machine-readable knowledge models are co-evolved by both technologists and users which support digitisation.

Keywords: international stability, knowledge engineering, culture, ethics.

1. INTRODUCTION AND BACKGROUND

Whilst we see increasing integration between political and economic spheres of the international system, the social dimension of international stability continues to lag behind, especially when it comes to the impact of emerging technological systems and models upon working life. A socially sustainable technology proliferation still eludes us. In this paper we argue that socially sustainable systems development approaches can be derived from a combination of new technological paradigms (especially knowledge engineering and smart data) which have been associated with the so-called “fourth industrial revolution” or Industry 4.0, which places knowledge workers at the heart of innovation capacity driving long term, sustainable growth across organisations in both highly industrialised and less developed regions (Caldarola *et al* (2018), Davenport *et al* (2002)). Recent research, although limited, provides initial evidence to suggest industry 4.0 factory environments can satisfy the goals of human dignity and improved productivity amongst knowledge workers by developing human-centred systems which improve the quality of working life and focus on worker health and well-being (Caldarola *et al* (2018)). This paper reflects on the unique differences between human and machine intelligences and introduces human-machine symbiotic, evolutionary development approaches. It extends the work of human centred systems in industry 4.0 settings into a very different knowledge work context: archiving cultural heritage, which has received little attention to date in IFAC.

Systems development methodologies provide frameworks by which human knowledge that impinges upon the technology project can be made explicit and expressed in a

formal language. Simply put, machine encoded knowledge is defined in terms of some identifiable patterns and some formal rules for processing those patterns (Gill (2019)). Machine reasoning is different in kind to human knowing. Not recognising this distinction, systems development has undermined human dignity in the workplace by devaluing human knowledge at the expense of overvaluing machine data processing capabilities (Cooley (2018)).

Epistemological Origins: Seeing into the Mind of God

Epistemologically, digital automation systems modeling paradigms focused upon codifiable knowledge can be traced back to seventeenth century enlightenment thought. Descartes attempted to construct a unified method by which to build a knowledge of a universe he envisioned as a natural machine. Later, Leibnitz set himself the task of formulating an exact language to describe this world based on mathematical formalisms. For them, the natural universe was a perfect machine designed and called forth by God. Using mathematics and a reductionist, empirical science this Divine perfection could be explored. In other words, for them scientific endeavor was a way of seeing into the Mind of God (Leibnitz, (2003)). The foundations laid by Leibnitz, Berkeley and many others provided a basis for new computational logics, and the emergence, centuries later, of computerised ‘reasoning machines’, artificial intelligence, database systems, programming languages and systems development methods by which to build such wonders. The dramatic engagement in the early Enlightenment epistemology resonated down the centuries in a scientific culture which has dominated western culture, framing the coordinates of what is considered “rational” (Foucault (1967); 1977). Systems development methods embody a

philosophy in which places human knowledge at the margins and codifiable knowledge at the centre in a techno-centric approach (Stapleton *et al* 2004).

2. NEO-TAYLORISM AND KNOWLEDGE WORK

Ciborra (2002) highlighted the way that our contemporary scientific discourse, as embodied in techno-centric systems development methodologies, was not suited to a rich understanding of the everyday dealings people have with technology. Almost twenty years ago Ciborra described how these technology-centric methods “dislodge the problem of human existence out of the development and use of systems” and “fill this ontological gap with the appearance of logic, objects, standards, and measurements... to... little avail” (Ciborra (2002) p. 104). Taylor’s vision saw humans as cogs in an industrial machine and human organisation as an engineering problem with an engineering solution in which humans had functions and completed tasks. Highly structured work methods shaped and controlled human work flows across vast mechanistic organisations (Cummings and Worley (1997)). Systems designs embodied a functional view of humans as intelligent machines (Stapleton & Murphy (2003)). This belied the fundamental epistemological distinction between human and machine intelligence highlighted and enshrined in the human-machine symbiotics which valorises human and machine in a relationship which makes the most of the unique capacities of each (Gill (1997)). This rationality and the culture from which it draws its power now dehumanises people in the workplace in a reincarnation of Taylor’s vision (Cooley (2018)). For example, this rationality is evident in “crowdwork” platforms which employ intelligent, infomediary technologies like those which connect customers with services in AirBnB and Uber. Crowdwork digital platforms are online labour exchanges which commodify labour itself (Bergvall-Kareborn and Howcroft, 2014). Work is broken down into small, well defined, micro-tasks usually less than a few hours long. These tasks are outsourced for a (usually tiny) fee. This has raised concerns about employee rights and exploitation in a globalised digital workplace. According to one report into Amazon’s crowd working platform “Mechanical Turk”, dissatisfied “requesters” often withheld payments for work without giving any explanation. Workers who attracted bad ratings could be blocked from viewing available work on the platform, without any grievance mechanism available to these workers. Amazon received a commission on each paid HIT, but did not intervene in disputes (Pooler, 2014). Crowd work like this is typically repetitive and simple but requires the human judgment and insight which computers are unable to offer. By 2015 these platforms had already become a major labour market in a variety of service sectors including financial services, IT, the arts and entertainment (Harms, DeSimone (2015)).

3. TACIT KNOWLEDGE AND KNOWLEDGE WORK

Tacit knowledge refers to a form of human knowing involving unspoken intelligence which is intrinsically very difficult to codify into machines, but which is an important

aspect of how people apply knowledge (Baumard (1999)). For Polanyi intelligent human activity involved a process of knowing which drew upon a knowledge tradition coupled with individual experience (Polanyi & Sen (1966)). This knowledge embodied in local practices and communities (O’Neill Somers (2019)). Polanyi (1961) defined tacit knowledge as “knowing more than we can tell” (p93) i.e. one can know how to perform a task but struggles to explain this performance to other people according to some logical formalism. This is in part because tacit knowledge is not quantifiable and is dynamically suited to the context in which it is employed and embedded in that context-of-use. Tacit knowledge can only be made known to other people through direct contact and socialisation (Nonaka *et al* (1996)). The non-communicability of tacit knowledge and its embeddedness in human activity makes it an invaluable source of competitive advantage to organisations (Baumard (1999)). It is continually accreted i.e. revised and re-learnt and it is contingent i.e. individuals make changes to their existing behaviour and knowing as circumstances change (Howells (1996); Roberts (2000)). Murphy (2009) showed how systems development methods do not address tacit knowledge and she drew attention to the need for technologists to inhabit the workplace where tacit knowledge is deployed in praxis, if they are to understand the implications of this knowledge for the development of manufacturing systems. More recently, O’Neill (2019) demonstrated the role of tacit and inter-generational knowledge transfer in e-agriculture automation technology adoption. She highlighted the socio-cultural forces stacked against farmers, forces which devalue contextual knowledge in favour of a scientific epistemology. Let us look more closely at relations between power, knowledge and rationalities in systems development?

4. POWER AND RATIONALITY IN TECHNOLOGY DEVELOPMENT

Power-relations exist under the surface of systems development which can have important social effects. This is not surprising given the structure of knowledge and the dominance of science in western culture (Foucault (1967; 1977), Sismondo (1996)). These relations play out in the cultural substrate of systems development praxis and draw from values which lay under the surface of the systems development community as a culturally distinct group (Carew, Stapleton (2015)). There are power dynamics which may remain under the surface shaping and informing systems development outcomes, often leading to suboptimal technical solutions. The conflicting interests of multiple parties with their different backgrounds, skills, concerns, priorities and perceptions can create particular challenges for systems development efforts.

Ovaska & Stapleton (2011) studied two large-scale mobile business applications development projects carried out by the software development department of an international technology business. The software development department was an internal partner for the company’s business units and assigned the task of developing mobile e-business services for both the global and domestic telecommunication markets

on the firm's mobile phone platform. Some of this work was also outsourced to software firms. To guide their service development activities, the software department had developed in-house methodologies and processes for developing the mobile phone solutions. However, business units of the parent company, who would have to deploy the mobile apps, were not fully comfortable with these processes and did not trust in their software development capability. "Quite often business units preferred outsourcing instead of developing in-house" (p. 43). The study found that significant power imbalances were evident in mobile e-business system development projects they studied. These imbalances and associated conflicts shaped requirements gathering and technology specifications in unforeseen (and unmanaged) ways. Technology-centred interests tended to dominate over other interests, including business considerations. The methodology software engineers used to guide their technology development effort overlooked this key aspect of the development process, centring on technical rather than human factors and power considerations. This resulted in solutions which were sub-optimal and these projects became very challenged. The study concluded that sense-making processes by which user communities made sense of their world had been ignored in favour of a techno-centric paradigm and this balance needed to be reset in systems development praxis.

The "Agile Manifesto" enshrined a back-and-forth between developer and user which shifted the power dynamics of development methodologies in the user's direction, a problem identified in the Ovaska & Stapleton (2011) study (Cohen *et al* (2004), Sutherland (2014), Jesse (2019)). In recent years this agile paradigm in which software systems are delivered in short sprints is being replaced with approaches more focussed on highly adaptive, real-time business-oriented approaches which prioritise the Taylorist principles of efficiencies and productivity but, like so many other methodologies, de-emphasise a rich understanding of the role of human knowledge at work (Rodríguez *et al* (2017)). Part of the problem is the need to create clear specifications, user stories or development goals prior to engaging in the sprint, scrum or other project methodology. This does not valorise the evolutionary nature of human understanding by which people come to understand and make sense of their world which has long been understood to be a central aspect of human learning and which was embodied in early human-centred systems methodologies such as soft-system (Checkland (1999), Weick (1995)). In this "sensemaking" perspective people come to understand their world of work by engaging with artefacts and tools, shaping and reshaping them in the process of use. This implies a quite different understanding of the development of an automation technology from the traditional view. In this context Ihde (2008) described a "designer fallacy" which assumes that designers of new technology can know *a priori* how users of the technology might engage with it. It is self-evident that knowledge-based organisations require an accretion-based, evolutionary, slowed down development process, at odds with the lean, efficient, rapid development methods so popular today. Before dealing with this point, the next section briefly reviews machine intelligence

applications which embody a much more evolutionary approach.

5. EVOLVING SMART DATA SYSTEMS

The Semantic Web is, in essence, a machine-processable web of smart data in which the data is addressable using universal resource identifiers which comply with W3C web standards (Kaehr (2004)). Recently semantic web ontologies have been deployed to control vocabularies in financial services (e.g. FIBO) and international development (e.g. United Nations Standard Products & Services Code (UNSPC)) amongst others. These ontologies incorporate web-based semantic knowledge models of linked data services providing interoperability across artificially intelligent systems. An explosion in unstructured data has meant that the automation of semantics and intelligence from unstructured data (text, graphics etc.) is an important research topic for intelligent control and automation applications (Assim *et al* (2018)). Linking complex data sets into a semantic web using languages like RDF and OWL implies an evolutionary development which records the emerging understanding of a domain that humans acquire as they engage with machine-readable complex, unstructured data. These smart data systems emerge from a process in which the web of linked data resources are, step-by-step, knitted together into a domain knowledge model which machines can process intelligently and from which meanings and insight can be inferred by both machines and people. Rather than an agile development in which rapid development is prized, or a structured methodology emphasising pre-planning, or DevOps in which Taylorist concerns with productivity and efficiency are central, this new, human-machine intelligence symbiosis centres upon expressing knowledge which a machine can process by weaving together the "quilt" of machine-readable knowledge in such a way that human tacit knowledge is augmented and enhanced. This in turn implies the need to establish a long, trusted relationship between knowledge workers and the ontologists and automation scientists who will provide the skills by which the patchwork of the quilt is formed into a full picture of the knowledge domain. It is speculated that, by incorporating the semantic descriptive logics of RDF and OWL in a human-machine intelligence capability, new web-based systems can be evolved which incorporate the best of both human and machine reasoning for the complex data sets of Industry 4.0 or archiving cultural heritage? What central principles could guide systems development?

6. THE COOLEY LAB & HUMAN-MACHINE SYMBIOTICS USING SMART DATA

Reviewing these implications of automation Cooley (1987) offered two stark alternatives:

1. Reduce human activity to bee-like behaviours, reacting to the systems and equipment specified for them but with little control over their lives.

2. Enable human architects via a new form of technological development which enhances human creativity and offers freedom of choice and expression.

Option 2 requires a cultural shift in systems engineering. A new Cooley Research Lab named in honour of Professor Cooley has been established at WIT. We have been utilizing our new *Cooley Lab* which acts as a test bed for complex design processes following Cooley's original claim of human-centredness. In the lab we evolve methods and tools which nurture "architects" rather than "bees" in a new *human-machine symbiotics* development approach which operationalises technology as a *tool*. Ethically this serves as a basis for more general systems development approaches more suited to solutions which augment the complex activities of *knowledge workers*. The Lab is a longitudinal action research project to explore the possibilities for intelligent automated applications for the curation of cultural heritage. Cultural heritage refers to physical artifacts, technologies and intangible traditions of culturally distinct groups. These may be inherited from past generations and are curated by highly trained experts for future generations. Although a great treasure of human civilisation, controlled and protected under UNESCO conventions, it is potentially threatened by the onward march of globalisation and automation (UNESCO (2019)). More details of the laboratory were reported in Stapleton *et al* (2019).

Curators engage with complex data sets and metadata encodings by which to organise cultural knowledge. They invoke rich interpretations and suggest implications for historical analysis and modern life. Simply put, they create a window through we come to understand what otherwise incomprehensible collections and archives *mean*. The curation process, which draws so heavily upon human intuitive knowledge and skill, is not amenable to being automated. Machine systems could support and augment curators in their work of caring for cultural treasures, if development process placed human knowledge at the centre of its focus. In the Lab methods of engagement based upon adapted participative action research (PAR) in which all participants are co-researchers and co-designers engaged together in different ways in the overall experiment (Torre *et al* (2015)). PAR is considered an ideal approach as it incorporates reflection and action to improve human conditions, often by reducing inequities which result from social power imbalances. Methods, tools, technologies and the technical products of the lab emerge from a complex matrix of interactions, interests, values and priorities of the academically and professionally diverse group. A major priority of the development methodology is to create a symbiosis of human and machine in which the concerns and capabilities of the knowledge worker are honoured and respected, and the technology is invited as an invited guest, having been shaped and reshaped by the back-and-forth interactions of technologists and users as co-creators of the system. In the PAR study, great emphasis was placed on the social dynamics and ethos which would be needed to "call forth" the technology as participants came to understand the ways that curators interact with cultural materials and the ways that technology might become an invited guest into

that process, supporting and enabling new possibilities in the curation of the treasures embodied by the cultural artefacts.

A Note on Digitisation and Integrating digitisation Metadata with the Semantic Model

Using contemporary methods, the starting point for any digital treatment of cultural heritage material, whether physical material or intangible elements such as dance, is the digital capture, or acquisition, of machine-readable data sets which describe and classify the cultural material. In the case of printed material, for instance, photography is often used to capture a high-resolution, colour-faithful renditions of objects under study. The Cooley Lab uses advanced photographic techniques such as Close-Range Photogrammetry and Reflectance Transformation Imaging (RTI) to capture objects in three-dimensional, or quasi-three-dimensional digital form. In processes for the digital acquisition of physical material, the primary phase of taking photographic images is typically manual although subsequent process computational phases are automated to a large extent. This workflow generates disparate but yet interrelated data collections, with metadata, that need to be archived in a cohesive and robust way. One route toward the long-term archival of this data is the use of software such as aLTAG3D (a Long Term Archive Generator for 3D Data) developed by the French Consortium for 3D Humanities which has been used to, for example, digitised complex Neolithic cultural materials (Grimaud & Cassen (2019)). This produces metadata about files used in archive generation and management, recording the life-cycle of the data in a way which is compatible with international metadata standards such as Dublin Core compatible. An example of the output is given below.

```
{{#depotArcheo}}  
<h2>Données archéologiques du dépôt</h2>  
<ol>  
<li>Nom du site : {{siteNom}}</li>  
<li>Propriétaire du site : {{proprietaireSite}}</li>  
<li>Propriétaire de l'objet : {{proprietaireObjet}}</li>  
<li>Lieu de découverte : {{lieuDecouverte}}</li>  
<li>Lieu de conservation : {{lieuConservation}}</li>  
<li>Numéro d'inventaire : {{numeroInventaire}}</li>  
<li>Description archéologique :  
  {{descriptionArcheologique}}</li>  
<li>Date archéologique : {{dateArcheologique}}</li>  
<li>Programme de recherche :  
  {{programmeRecherche}}</li>  
</ol>  
{{/depotArcheo}}
```

7. SYNTHESIS: THE ENRICHER DEVELOPMENT PARADIGM

Rather than seek to automate human activity, workplace automation and control technologies could be developed so that human intelligence and knowledge-based activity is placed at the centre of a systems development effort. The development effort therefore shifted focus away from automating and exploiting human knowledge and skill, to a focus on how humans might take advantage of a machines

unique capacity to intelligently process very complex data sets much more quickly than humans, freeing up people to do the difficult work of interpreting and reinterpreting the archival materials. This subtle shift in design emphasis meant that technology became an “invited guest” into the workspace, rather than a dominating power which, uninvited, shaped and controlled peoples’ working lives (Ciborra (2003)). As a result of this general approach it was clear from the participants that the first challenge was to enhance the existing metadata standards used by archivists. This would be the basis for a new system architecture centred around a semantic model for archived materials. The standard would enable interoperability and ensure that the basic metadata that archivists needed to collect could be supported whilst allowing this metadata to be extended as an understanding of the significant conceptual relationships across archived knowledge emerged. In another paper we have set out the outcome of this initial phase in which global metadata standards were evaluated (O’Neill *et al* (2019)). As work with archivists proceeded a development process emerged with the following features:

1. **Ethos Centric:** ethos of development continuously revisited and reviewed. Important to articulate and re-articulate core values of development.
2. **eNgage**ment as an Outcome: Shift from “why are we doing this” questions to “how are we engaging together on this” question.
3. **Reuse Machine Knowledge:** Reuse and extending existing knowledge models rather than predefining total schema where possible before implementing.
4. **Insights from Context:** Derive technology to fit the context—of-tacit-knowledge-use. Means acquiring an understanding of knowledge-in-action to drive software creation and technology development.
5. **Co-evolution:** co-evolve the methodology and the technology with all participants. Also, co-evolve and reshape work-technology symbiotic relationship.
6. **Hospitality:** Technology “guest” invited into the work context, otherwise not deployed.
7. **Expressiveness:** Semantics emphasise expressiveness of the machine model rather than processing efficiency and technical capability (which come later).
8. **Reverse Engineer and Extend Semantic Model:** Constantly reverse engineer from data and metadata resources and standards as a way of building the knowledge model, extending the model and integrating the resources semantically.

8. CONCLUSIONS

AI and robotic systems are emerging which embody a new dehumanising Taylorism. There are also tremendous new opportunities to create systems which dignify and value the complex work in which people will engage in the next decade. The human-machine symbiotic systems are now becoming possible. These will be developed through evolutionary, slow, contingent praxis. The technologies,

which include smart, linked data and web-based machine intelligence demand a new evolutionary paradigm of intelligent automation systems creation. At a time when we run the risk of dehumanising knowledge work through outdated cultural assumptions, ENRICHER offers a human-knowledge-centred development paradigm. Although this work is in its early stages it suggests new areas of research for the IFAC community. It presents a radical shift in development methodologies, and even in the culture of systems engineering communities.

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