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INTELLIGENT CONTROL AND AUTOMATION SYSTEMS:

Mike Cooley's Vision of Socially Responsible, Human-Centred Technology

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Abstract: Michael Cooley was a founding member of the Human Centred Systems movement, which argued for a symbiosis in which the complementary strengths of machine and human were balanced in the development of automation and control systems. Cooley's pioneering work and the research that followed, placed social effects and human factors at the heart of intelligent human-machine systems development and profoundly influenced the CC9 group of IFAC technical committees. In this paper we concentrate on his vision of human-machine symbiotics, applying it to web-based intelligent systems engineering. Following a survey of the literature the paper concludes that human-machine systems engineering praxis, as embodied in contemporary ontology engineering methodologies, overlooks critical aspects of human knowledge and craftmanship. Some basic principles are established by which to enhance and reframe systems development methodologies, and human-machine control and automation systems engineering research trajectories are offered to address the gaps.

Keywords: knowledge engineering, ethics.

1. THE HUMAN CENTRED SYSTEMS MOVEMENT

Michael Cooley was a founding member of the Human Centered Systems (HCS) movement which valorized human knowledge and skill in the development of human-machine systems. This was very influential in the CC9 group of IFAC technical committees. For example, TC 9-2 organized a symposium with major contributions to the human-centered systems literature and IFAC contributions at the 2004 IFAC Conference on Control Strategies for Social and Economic Systems (ACS, 2004) as well as at more recent events such as TECIS 2018 and 2019, featured human centred systems papers drawing on Cooley's legacy. This paper asks:

What are the implications of Cooley's vision of socially responsible technology for contemporary systems design and development?

Cooley's systems science approach, which remains a basis for developing human-machine control and automation systems, insisted that the ethos and goals of systems development projects must center on the empowerment and emancipation of human beings and, by extension all life on this planet. In the 1970s Cooley already noticed the political dimension of the scientific method as applied to technology design (Cooley (1976)). Power dynamics, expressed in conflicting interests of multiple parties with their different backgrounds, skills, concerns and priorities challenges systems development efforts but are rarely explicitly considered during development. Ciborra (2002) highlighted how contemporary scientific discourse, embodied in systems development methodologies and praxis, is unsuited to a rich understanding of the everyday dealings people have with technology. This, in turn, raised ethical concerns about assumptions, control and automation scientists make, about technology in relation to humans in the workplace. Within IFAC, work in this field exposed deep social structures embedded in the systems engineering discourse which can obstruct an inclusive engineering ethics (Stapleton & Hersh (2003)). A socially-responsible development praxis must consider the "other" in relation to the "self", and narrative ethics has been proposed to explore this relation (Hersh & Stapleton (2005); Hersh (2016))), where this "other" might be someone or something embodying a difference to myself such as a technology or a belief. Hersh challenged us to open up a richer discourse about the social impact of technology which, in turn, would inform a socially responsible design praxis based on creating a space in which other voices, besides the dominant, scientific voice, is heard. IFAC established a Diversity and Inclusion Task Force, signalling its sense of IFAC's social responsibility as a global community. Technical committee TC 9-5's new Working Group on Diversity and Inclusion comprises researchers from over a dozen countries, representing a range of disciplines. Cooley envisaged social responsibility, applied to automation, as bringing in those at the margins, and up-ending dominant power structures (Cooley (2018)). These debates are again gaining momentum, not least as a result of developments in AI and robotics in the automation of the services sector which mirror the automation of manufacturing decades ago, and which was the focus of Mike Cooley's analysis. In contemporary manufacturing "Industry 4.0" also creates challenges. and opportunities for a engineering ethics in relation to human skill and creativity. All this suggests the need for a new ethics of artificially intelligent machines in a workplace which rejects any new Taylorism which reduces humans to cogs in a web-based

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intelligent machine (Colclough (2017), Cooley (2018)). This brief review suggests an important question:

How can intelligent web technologies be designed and developed in a socially responsible, human-centred way?

In IFAC, Groumpos drew attention to the risks associated with a poor understanding of intelligence in human-machine systems for intelligent control (Groumpos 2016; 2018; 2019). His critique of human wisdom versus machine intelligence drew attention to risks associated with any over-reliance on machine intelligence and unrealistic expectations of intelligent machine capabilities. He emphasised human wisdom as a core aspect of any human-machine system involving intelligent control. Rather than imputing "human-like" intelligence to machines, Gill (2018) showed how socially responsible systems design is predicated on an understanding of the *differences* between human and machine intelligence. This is a basis for human-machine symbiotics for intelligent automation (Gill (2018); (2019)). In a human-machine symbiosis, humans and machines will reason, act intelligently and complement each other, with some forms of knowledge more suited to machine agency and some more suited to human agency. AI involves the processing of formally encoded (in some logical formalism) rules and facts about some world under scrutiny. Whilst, these days, AI systems can process probabilistic information about the world, Gill has pointed out that they remain constrained by a need to codify patterns, rules and facts. Humans are unable to match the processing speeds of many machine-reasoning systems for this kind of knowledge. However, human craft and insight comprises knowledge of a markedly different kind which is not readily codifiable. Cooley drew attention to the importance of tacit knowledge involving unspoken intelligence which is embedded in the context in which it is used. It is unspoken because one can know how to perform a human intelligence task but struggle to explain how it is completed in a logical formalism (Polanyi (1961).

The Value of Human Craft in the Digital Age

Cooley was passionate about human skills involved in crafting artefacts. He believed that human-machine systems should enhance human skill, craft and ingenuity (Cooley (1987)). In a digital society, a major generator of wealth is innovation, creativity and craft. As intelligent systems free people from routine, mind-numbing tasks which reduced humans to cogs in a machine, a workplace in which human craft and creativity becomes the primary source of value became possible. It requires a human-machine symbiosis in which machine and human co-exist to craft creative solutions to social challenges. These systems make possible a new "global laboratory" in which machines intelligence assists human decision-making and in turn, enhances social communication, cognitions, creativities and skills (Brandt, 2007; Gill, 1986). When it came to valorising human craft skills and creativity, Cooley (1976) recognised structural problems in the ways in which industrial societies were organised. In his analysis of fixed capital in industrial settings he noted how this capital emphasised formal, rule-based logics as the primary source of value. Expensive, fixed capital investments in machines demanded that humans work to machines, rather than the other way around. This devalued human knowledge, craft, and ingenuity, emphasising the Taylorist machine view of organisational life. To explore this further, let's take the example of how nurses add value to care service provision. Sennett describes 21st century challenges associated with recovering "medical craft" in a quantified, mechanised, automated society which valorises science above other, care-based, rationalities (Sennett (2008) p. 48). In industrial societies medical craft (as distinct from science) is devalued. Nevertheless, sick people cannot be repaired like automobiles nor mental health reduced to an industrial process of fixing broken bits. Studies of nursing praxis in the nationalised health service of Britain have revealed how nurses listened and paid attention to, not only elderly peoples' complaints about their aches and pains, but also to their stories of grandchildren and extended families as a key aspect of their care for these people. Nurses stepped into a breach, providing ingenious interventions, even when neither qualified nor legally obliged to do so. The heartbeat of nursing is caring: this is the core value, the culture, the systemic purpose of nursing. Nursing craft can be demeaned in mechanised data-driven working environments. On the other hand AI can complete routine, intelligence tasks, such as completing online forms and data entry. This frees people to be creative, caring and smart. This may enable craft-workers to recover their historical position as drivers of value in a revitalised, craft culture in which human and machine exist symbiotically.

2. ONTOLOGY DEVELOPMENT

Knowledge-based systems on the web encode ontological knowledge about the human world into a machine-readable form. Figure 1 summarises a well-known development methodology which has appeared in recent IFAC research papers (e.g. Thakar *et al* (2018)). Technical frameworks for developing ontologies are also available e.g. OWL2 semantic level uses an OWL API and Java as the language/interface (Hebeler *et al* (2009)). The ontology engineering process does not pay much attention to the distinctly human aspects of knowledge as embodied in the *bricolage* of everyday working life (Ciborra (2004)). For example, the "Determine Scope" stage identifies the range of users and the purpose of the ontology and the questions the ontology should answer, but not factors associated with knowledge and creativity in the workplace. What principles might re-orient ontology engineering as a human-machine symbiotic approach, rather than one focussed on functional properties of the intelligent system? For Ciborra (2004) the organisation is a "host" with a distinct identity and culture and new technology is the "guest", a "stranger" (in the sense of an "other" seeking entrance to the hosts world). This process must bridge the discontinuities between the worlds of human intelligence and machine intelligence, discontinuities implied by tacit knowledge and human craft on the one hand and codification required by formal machine logic on the other. Bridges include sense-making, learning, adaptive and co-evolutionary processes by which humans come to accept and appreciate the technology (its capabilities and limitations). Ontology engineering can create a space co-evolve the human and machine aspects of the socio-technical system, producing symmetries between human intelligence tasks and machine learning capabilities. Ontologies can formally capture these symmetries, encoding emerging knowledge about the world in which the human finds themselves as they live out their lives.

Figure 1. Overview of Ontology Development Process (adapted from Noy & McGuiness (2001)).

Gill (2019) emphasised holonic thinking in the analysis of any complex human-machine systems context. The development process in figure 1 does not facilitate (or even mention) the exploration of holons in the complex, social system as an intrinsic aspect of the knowledge capture process. Soft Systems Methodology (SSM) offers a partial solution to this challenge. SSM explores the human activity system context, and records this exploration in a rich picture which, as it develops, reveals important holons (Wilson & van Haperen (2015)). These holons can be organised according to various mnemonics depending on the particular context and purpose of the systems engineering effort. We propose an analysis and exploration of the holons so as to include **B**eneficiaries and **V**ictims of the system and the **E**nvironmental impact and ethicality of the system transformations (this is found in the mnemonic "BATWOVE" adapted from the original CATWOE mnemonic (Midgley & Reynolds (2001), Midgley *et al* (2005)). Beneficiaries and victims may include people but also ideas and meanings such as, for example, important knowledge passed down as part of a cultures heritage. In SSM conflicting interests and tensions can be expressed and their meanings captured in a rich picture of the holons, without one perspective dominating another. The back-and-forth between conceptual and real world analyses inherent in SSM drives the engineering effort towards a transformative conceptualisation of the new human-machine system and helps uncover systemic "root" definitions which express the core purpose of the system. This mirrors the development of conceptual and real world models central to ontology engineering, and SSM can readily integrate into that aspect of ontology development. For ontology engineers SSM can uncover dominant narratives, laying bare the assumptions and beliefs about what the system "is" and "what it should become". It can also develop control metrics by which to assess and regulate performance in the system (Checkland (1999)). SSM can also be used to elicit knowledge about a complex context in which a system is to be deployed, and may be well suited to capturing and organising complex knowledge during later stages of ontology engineering. Although the ontology engineering literature has paid little attention to SSM, it has been successfully incorporated into other software engineering methodologies (e.g. Salahat, Wade & Lu (2008)). It is therefore a good candidate methodology for supporting human-machine symbiotic system solutions for intelligent, web-based systems where there is a high likelihood of conflict and competing interests.

3. SYNTHESIS

We will now return to the two questions posed earlier:

How can our new intelligent technologies be designed and developed in a responsible, human-centred way?

For Cooley, human-machine symbiosis is an antecedent for socially responsible technology in the 21st century workplace and the intelligent machines which populate it. This paper briefly reviewed ontology engineering as a contemporary systems development activity involving the creation of intelligent web-based systems, and has proposed enhancements to the functional approaches opposed by Cooley (Cooley (2019)). We place human knowledge and craft at the centre of human-machine systems development, thereby providing an opportunity for a unique, contextualised interplay between human and machine which valorises human knowledge and craft. The literature survey has revealed ways by which human-centred, socially responsible development can proceed. However, the power dynamics Cooley showed were structurally present in industrial societies have not been fully addressed here either and more research is needed. A more sophisticated methodological framework is needed to guide human-machine systems development in this regard. In short, more work is needed to confirm the validity of these principles in practice. The INSYTE-Cooley Laboratory at WIT in Ireland is experimenting with these principles as it constructs web-based intelligent systems with the curation staff who care for Irish cultural heritage in the archives. Whilst early results are promising, time will tell if we successfully honour Mike Cooley's tremendous intellectual legacy and vision of human-machine symbiotic systems.

Q. *What are the implications of Cooley's vision of socially responsible technology for contemporary systems design and development?*

Cooley believed that society needed automation technologies which did not demean human workers but, instead, empowered and valorized them. To deliver on this goal development processes must strive for human-machine symbiosis. We have briefly shown that there is a sufficient theoretical basis for emerging web-based intelligent systems to be constructed and deployed in ways which are true to his vision. Methodologies clearly exist which, when brought together, provide a basis for human-machine symbiosis. Given the opportunities and challenges facing society into the 2020s, including industry 4.0, `the automation of services and the rapid move to remote working ushered in by the recent COVID 19 pandemic, we can conclude that Cooley's insights remain vitally important. This paper has shown how control and automation science has the means and technology to deliver on his vision of socially responsible intelligent automation systems.

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