Allocation of Function in the era of Artificial Intelligence: a 60-year old paradigm challenged

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ABSTRACT

The Fathers of the discipline of Ergonomics and Human Factors used their scientific research and real-life experiences of technological development during WWII and the first years of peace that followed to propose a set of principles for Human-Machine Interaction (HMI). These principles stood the test of time and informed common applications of the discipline, such as allocation of function between human and machine for many years. It is only recently with the advancement and generalisation of certain underlying technologies that forms of Artificial Intelligence (AI), machines and systems with non-deterministic behavioural characteristics became operational. The underlying specification of those machines and systems appear to challenge some of the underlying assumptions made by the Fathers of the discipline. The present article revisits those principles of HMI, identifies the changes in the underlying assumptions and discusses the implications of the changes identified to the discipline of Ergonomics and Human Factors.

KEYWORDS

Ergonomics History, HMI, Allocation of Function, Artificial Intelligence

Introduction

It is the year 1951. Significant amount of research work tagged as "Human Engineering", "Engineering Psychology" "Human Motion" studies during WWII, has only just gained its own niche under "Ergonomics" or "Human Factors", respectively east and west of the Atlantic Ocean. The Ergonomics Research Society (the predecessor to the Chartered Institute of Ergonomics and Human Factors) in the United Kingdom is only a couple of years old and the Human Factors Society (the predecessor to the Human Factors and Ergonomics Society) in the USA and the International Ergonomics Association globally are still to be conceived. The wheels are in motion towards the formation of both organisations, predominantly fuelled by the excitement to share knowledge globally and implement in commercial applications the expertise attained during the war effort.

Against that background a team of scientists – many of whom would go on to play a seminal role in the establishment of the discipline of Ergonomics and Human Factors – published a report on the human role within the emerging system of high-capacity civil aviation (Fitts, et. al, 1951). Within that problem space, the report suggests six capabilities where human performance is superior to machine performance and six capabilities where machine performance exceeded that of most humans. The six abilities identified as human superiority by Fitts et al (1951) were:

1. Detection - very low energy requirements to stimulate sensory receptors.

- 2. Perception ability to generalise a stimulus, i.e. identify an object under different environmental conditions.
- 3. Improvisation the ability to attempt multiple solutions to the same problem.
- 4. Long-term storage the ability to maintain and access information selectively when needed in the long term.
- 5. Induction the ability to use reasoning and formulate new hypotheses (and if confirmed, knowledge).
- 6. Memory as in long-term storage above.

The six abilities identified as machine superiority were:

- 1. Speed beyond the nominal 200ms response times of humans
- 2. Power mechanical power already exceeded muscular strength from the Classical Times.
- 3. Routinisation the ability to reliably perform the same function over and over again.
- 4. Short-term storage the ability to store and quickly access recent information, before erasing it completely to make memory available for the next task.
- 5. Deduction the use of available information and the complex computation of results.
- 6. Performance of simultaneous operation computing/performing operations in parallel.

The above principles, based on the same findings, were later somewhat expanded in Fitts's seminal paper "Engineering Psychology" (1958).

Reeling 70 years forward

The number and quality of developments pertinent to the relationship between Human and Machine far exceed the scope and length of this article; Ergonomics and Human Factors grew both in breadth – Professional Societies established in all five habitable continents – and in length, with some of the older societies enjoying membership figures in the thousands. The explicit and implicit demand for Ergonomics/HF expertise has arguably never been greater and the fruits of the integration of such expertise in products and services are enjoyed by societies around the world. The relative merits of human and machine as proposed by Fitts et al (1951, 1958) however have largely been accepted as academically valid, quoted in multiple textbooks on the Ergonomics and Human Factors (e.g. Dul & Weerdmeester, 2003; Sanders & McCormick, 1992) and informed allocation of function between human and machine in industrial applications.

The specification of machines – to which ergonomists often contributed – and the layout of the sociotechnical systems within which those machines operate increased in complexity, much like Fitts assumed back in the 1950s. Thus, a modern car or aeroplane with its human crew today performs simultaneously and in sequence far more functions than its predecessor performing the same mission back in the 1950, but even more so the wider transportation system within which the aeroplane with its aircrew operate has increased the number interactions between its constituent entities. The societal benefit of such growth in complexity is the increasing efficiency, accessibility and affordability of transportation and communication.

Since the birth of the discipline of Ergonomics and Human Factors – and even before then, determinism has been a cardinal principle adopted by engineers designing mechanical, electric and electronic components and systems. From the levers and pulleys of Archimedes, to the million lines of code in the software of a modern road vehicle the intention is to maintain a fixed relationship between the human customer, user, operator and output from the machine. This is the basic Human

Machine Interaction (HMI) loop (Figure 1) suggested by Chapanis (1976) and often adapted in textbooks on Ergonomics (Dul & Weerdmeester, 2003; Sander & McCormick, 1992).



Figure 1: Fundamental HMI loop

It is hard to pinpoint the exact timing when and which application broke the fixed relationship between input and output. Machine Learning theories and concepts were devised as far back as the time of the Fathers of Ergonomics (Samuel, 1959). Until recently however, Machine Learning models hardly left the lecture theatre or the laboratory. Data availability – through incremental growth in storage capacity – and data accessibility – through growth and speed of communications, made Machine Learning applications economically viable and competitively advantageous. Flexibility and adaptability to a rapidly changing environment became a desirable emerging property of the machine and the system in which it operates. **Adaptability** is the most decisive capability in the natural world (Darwin, 1859). The term "Artificial Intelligence", often abbreviated to "AI" is used to describe machines and non-deterministic systems which include Machine Learning methods in their operations.

Mainstream media use the term "AI" to include many systems, applications and apparati whose behaviour has been programmed or specified deterministically e.g. fixed rule-based experimental autonomous vehicles (British Broadcasting Corporation, 2018) and many image processing applications lacking any learning/adaptation features. A comprehensive article is required to provide the evidence supporting the logical argument against such relaxation of the definition of Artificial Intelligence. For the purpose of the present article, it should be sufficient to highlight that in the absence of the adaptability/learning capability, no matter the quantitative increase in pre-set input/output links, the fundamental HMI loop remains valid as is (Figure 1), with only the number of iterations and the number of predetermined valid input and output values increasing. The paradigm shifts as soon as the adaptability feature comes into play.

With the fixed relationship between human input and machine output broken, and replaced by a learning and adaptation mechanism adapting the feedback or output to a number of parameters in the system environment (including the human input itself), the machine has the potential to perform functions and in environments that potentially exceed those envisaged by its creator. Figure 2 presents a generic Machine Learning concept and how that remorphs the established HMI loop to a Human – AI loop.



Figure 2: Human - Artificial Intelligence (AI) Loop

The rigid link between human and machine agents is broken through a machine learning function that continuously generates candidate outputs to any given input. In parallel, human input is no longer a plain control input, but also acts as feedback and informs both the machine learning function and the selection mechanism that determines the corresponding machine output. Thus, both the list of candidate machine outputs and the method by which the next output is selected can be continuously altered with every input.

Discussion

The adoption of Machine Learning by machines and the transition to a Human – AI loop (Figure 2) challenges the long-standing principles in the discipline of Ergonomics and Human Factors. First, human superiority in the ability of improvisation, the ability to attempt multiple solutions to the same problem challenged by default when interacting with AI, as in fact multiple solution generation and identification of best fit to data is what most Machine Learning methods do. Abilities like long-term data storage and human memory superiority are convincingly challenged by the advances in electronic memory capacity and network speeds that made off-board "cloud" computing seamless and AI approaches feasible. Machines nowadays boast virtually unlimited storage and effective long-term recall through Machine Learning, including the **ability to induce** rather than simply deduce information, pattern and traits in the accessible datasets. Machine Learning has altered the HMI paradigm as demonstrated above, but it is that capability to induce information - and eventually, knowledge – that opens wide a world of opportunity for societal advancement. Pharmacological discoveries and therapies have been publicised recently (Flemming, 2018) and other areas could follow soon.

The human agent still influences system output through their own behaviour and can still be assumed in control of function enactment. On the other hand, the more capable an AI application is in inducing information, the closer to impossible it is for the human(s) who interact with it to interrogate the application, comprehend the logical steps, the reasoning, and build a mental model of how the AI generated the output experienced. It is therefore predictability and assurance that is sacrificed for ingenuity and innovation. For example, when a drug discovery system generates the chemical identity of a new drug, it uses learning methods which are designed in by a human system designer/programmer, in order to generate its own method of searching, cataloguing, compiling all available information, and make a beyond human experience number of iterative formula generator can

feedback whether that formula does the job he/she intended; however, unpicking the exact logical and mathematical steps the system performed within hours or days, would take the human operator a very long time...

Furthermore it is out of the cardinal principle of determinism in the Input-Output loop that automation itself was born. Automation offered repeatability and in theory at least, absolute reliability – the ability to provide exactly the same output over exactly the same period for a given input, exactly as per design intention. Paradoxically, AI applications replace such automation with flexible adaptation. They sacrifice some of the "routinisation" superiority for relative gains in flexibility. In that process, they make established procedures in safety assurance, qualification and certification trivial or even impossible with existing methods, which are built on the concept of determined effect for given input and collation of evidence that support such claims.

Overall, with detection thresholds and energy requirements of modern sensors vastly improved since the time of Fathers of Ergonomics and Human Factors, it appears only machine superiority in the abilities of speed, power, short-term storage and parallel processing remain unchallenged. It is however worth remembering that as in the past, so is today that machines – including the ones which can design and build other machines – are designed and built by the ingenuity and labour of humans. Even if the loop is shifting from HMI to Human-AI Interaction, and some of the terms under which that interaction is defined need to be updated, this is still the space for the discipline of Ergonomics and Human Factors to research, develop and provide methods and solutions to a growing technical field in society. Revisiting some of the principles established by the pioneers in the field is arguably a useful starting point.

References

- British Broadcasting Corporation (2018). Driverless Cars. BBC Focus Magazine. Accessed online: https://www.sciencefocus.com/tag/driverless-cars/
- Chapanis, A. (1976). Engineering Psychology. In M.D. Dunnette (ed.) *Handbook of industrial and organizational psychology*. Chicago, IL: Rand McNally.
- Darwin, C. (1859). On the origin of species. London, UK: Routledge.
- Dul, J. & Weerdmeester, B. (2003). Ergonomics for Beginners. London, UK: Taylor and Francis.
- Fitts, P. M., Chapanis, A., Frick M. C., et al. (1951). *Human Engineering for an effective Air-Navigation and Traffic-Control System*. Washington, DC: National Research Council.
- Fitts, P. M. (1958). Engineering Psychology. Annual review of psychology. 9. 267-94.
- Flemming, N. (2018). How Artificial Intelligence is changing Drug Discovery. Accessed online: https://www.nature.com/articles/d41586-018-05267-x
- Samuel, S. L. (1959). Some studies in Machine Learning using the game of chequers. *IBM Journal* of *Research and Development*, *3*,(3) 210-229.
- Sanders, M.S., McCormick, E.J. (1992). *Human Factors in Engineering and Design*. New York, NY: McGraw-Hill.