Artificial Intelligence & SE – “All your use cases belong to us”

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Categorisation

- Accessibility: BEGINNER
- Application: SE Life Cycle Process Automation
- Topics: Artificial Intelligence, Automation, Transformation, Digital, Capability

Abstract

Systems Engineering (SE) weaves capabilities, conditions, and constraints of humans and machines to deliver stakeholder value. Augmentation and automation of tasks that would otherwise be performed by humans is inherent in planning and execution of associated life cycle processes and products. As Artificial Intelligence (AI) and Machine Learning (ML) technologies continue to disrupt sectors, there is growing interest and concern about the role of knowledge workers in the face of automation. This paper summarises study of these technologies and prospective SE life cycle process applications with reference to a fictitious brief to develop a concept automated grocery delivery service. As an INCOSE Certified SE Professional (CSEP), International Requirements Engineering Board (IREB) Certified Professional for Requirements Engineering (CPRE), and Chartered Manager and Fellow of the Chartered Management Institute (CMI), the author highlights power and potential of emergent capabilities to augment and automate diverse administrative and more creative and generative SE tasks. Systems Engineers however are expected to continue as principal agents in identifying and harnessing these technologies. The paper concludes by providing insights for the SE community to lead and manage changes in this field.

Introduction

SE is a complex socio-technical endeavour that works to weave capabilities, conditions, and constraints of humans and machines to deliver stakeholder value (INCOSE, 2019). Augmentation and automation of tasks that would otherwise be performed manually is inherent in planning and execution of associated life cycle processes and products. Solutions conceived, developed, and deployed span everything from factory and production line operations through to remote inspection, characterisation, and transport of nuclear waste. Effectiveness, efficiency, quality, reliability, and safety gains resulting from engineered solutions are generally appreciated. Displaced actors however tend to resist and rue change (Kotter & Schlesinger, 1989). Fear and wonder escalate with more substantive developments.

Artificial Intelligence (AI) is a contemporary disruptive force (Sallomi, 2023) with applications increasing across sectors, from agriculture, education, and entertainment to healthcare, retail, and transport. Developments in Machine Learning (ML) and Chat-Bot technologies specifically have led to exploration and use across broader roles and tasks, from copywriting to technical research and

summarisation. OpenAI is a leading research and development company in this space, whose stated aim is to bring AI benefits to all of humanity (OpenAI, 2023). Using a sophisticated Language Model, Training Data, and Reinforcement Learning from Human Feedback (RLHF) their developing flagship product, ChatGPT, has the capability to return compelling outputs and answers to user prompts. Commentary and speculation on opportunities and effects for work and wider society naturally follows the rapid pace of allied developments. Critical reflection on roles and responsibilities is therefore key.

Systems Engineers may quickly envision how manual and mechanical tasks may be adapted but what might developments in AI and ML mean for conventional knowledge workers "who apply theoretical and analytical knowledge, acquired through formal training, to develop products and services" (Drucker, 1959)? What does the rapid rise of these technologies mean for SE? What of roles, responsibilities, and use cases that belong to the Systems Engineer?

This paper is intended as a provocation on prospective uses of AI in planning and execution of SE life cycle processes and consolidates author studies, with summary of approach, results, observations, and reflections to enable the SE community to lead and manage associated change.

Approach

As an SE working to develop people and practise across Sellafield Ltd (SL), its supply chain and wider Nuclear Decommissioning Estate (Gibson, 2020), the author identified AI as a focus for Continued Professional Development (CPD) and engagement through 2023. Early outputs were drafted as a series of demonstrative provocations[1] and shared with a network of industry colleagues to promote awareness of emerging capabilities, opportunities, and issues arising. Extended study was invited by the SL Chief Systems Delivery Engineer (CSDE) to promote awareness and inform developing organisational strategies.

Noting interests in early life cycle development and general accessibility, as well as restrictions on disclosure of sensitive information to a commercial third-party hosted service, the author assumed a fictitious brief to develop a concept autonomous grocery delivery service.

Activities that an SE professional may be expected to complete in course of addressing this brief were identified with reference to SE Life Cycle Processes (ISO 15288, 2015) and corresponding INCOSE SE Handbook elaboration (INCOSE, 2015). ChatGPT prompts and products were crafted accordingly to review capabilities across these Use Cases, from Drafting an Enterprise-Level ConOps and Deriving Business Needs as Preliminary Life Cycle Concepts through to Deriving Measures of Effectiveness (MoE) Information Needs from a Business Requirements Specification (BRS) and Using Primary System Functions to Draft an Operational Concept (OpsCon).

SE-ChatGPT Use Cases were identified with an ID / Title and corresponding purpose(s) as follows:

UC-03 – Deriving Business Needs as Preliminary Life Cycle Concepts	*To demonstrate automated draft of business needs from a pre-existing ConOps and output as preliminary acquisition, deployment, operation, support, and retirement Life Cycle concepts for a solution.*

[1] - Demonstrations covered magazine copyrighting, technical role specifications, interview questions and assessment prompts, software development, competency frameworks, training course outlines and more. See author for information.

SE-ChatGPT Use Case progression and product cascade were modelled as follows[2]:

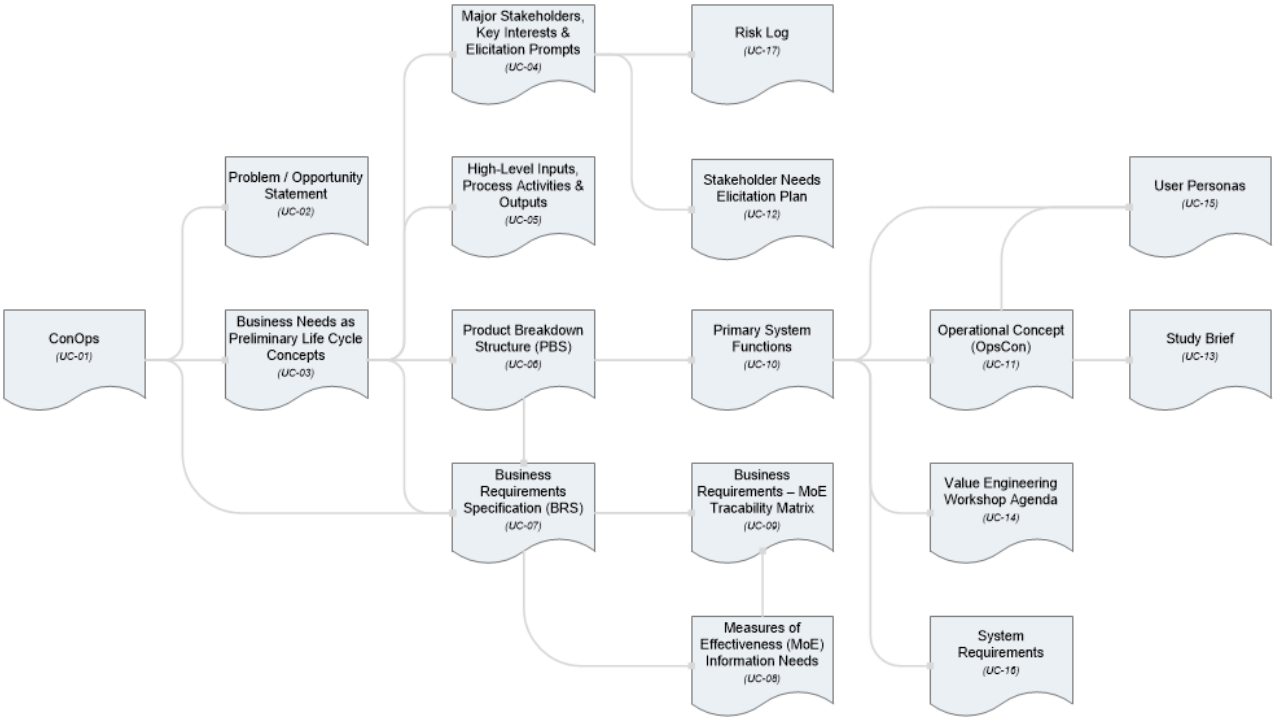

Figure 1 - Use Case Progression

Development and iteration of ChatGPT prompts reflected service capabilities, training data limitations, and output conformity / quality revealed in use. User prompts and products were collated and reported to the SL CSDE, Project SE Management (PSEM) Capability and extended Community of Practise (CoP) with life cycle stakeholder engagement on summary findings following. Observations and conclusions were updated and included in a final report which was shared with Enterprise Leads to support encompassing strategy development.

Result

This study demonstrated present capability of AI technologies to support SE Life Cycle Processes. SE-ChatGPT Use Case outputs were mostly generated from 1-3 short sentence prompts with results summarised below. Higher-level observations and conclusions are presented following.

UC-01 – Drafting an Enterprise-Level ConOps	Summary contextual information (on company, service, region, strategic intent), an inline ConOps definition drawn from INCOSE SE Handbook (INCOSE, 2015), and prompts to quantify scope of operations were automatically translated to a draft of x6 paragraphs that succinctly frame company assumptions and intent in relation to operation of a new autonomous grocery delivery service.
UC-02 – Drafting a Problem / Opportunity Statement	The drafted Enterprise ConOps was translated to a succinct high-level problem / opportunity statement using a single short prompt.

[2] – Life cycle stages, processes, and products are subject to respective organisational / project tailoring.

UC-03 – Deriving Business Needs as Preliminary Life Cycle Concepts	The drafted Enterprise ConOps and inline definitions from INCOSE SE Handbook (INCOSE, 2015) were used to automatically draft Preliminary Life Cycle Concepts (i.e. acquisition, deployment, operation, support, retirement).
UC-04 – Drafting Candidate Major Stakeholders, Interests and Elicitation Prompts	Preliminary Life Cycle Concepts and table column prompts were used to automatically compile a list of stakeholders, identifying references, corresponding interests, and needs elicitation prompts.
UC-05 – Drafting Candidate High-Level Inputs, Process, and Outputs	The drafted Enterprise ConOps was automatically translated to a high-level input, process, output table, noting noun/verb-noun forms.
UC-06 – Drafting a PBS Based Upon Preliminary Life Cycle concepts	Preliminary Life Cycle Concepts were used to automatically draft a Product Breakdown Structure (PBS) representing high-level elements or components of a candidate solution, associated identifying references, name, and description.
UC-07 – Drafting a Business Requirements Specification	The drafted Enterprise ConOps, Preliminary Life Cycle Concepts and PBS were automatically translated to a Business Requirements Specification (BRS) representing high-level capabilities and intent of the new automated grocery delivery service. Extended requirement attributes included ID and rationale. Requirements specialists may contest abstraction and syntactic rendering.
UC-08 – Deriving Measures of Effectiveness (MoE) Information Needs from a BRS	The drafted BRS was used to automatically derive a list of corresponding MoEs, with extended ID and description attributes.
UC-09 – Drafting a Traceability Matrix for Candidate Business Requirement-MoE Links	Candidate links between BRS requirements and MoEs were automatically identified and rendered in a traceability matrix. Nominal prompts were required for formatting columns and intersection marking.
UC-10 – Drafting Primary System Functions	Primary System Functions were automatically drafted for a pre-defined product / system with corresponding conditions, constraints, and rationale.
UC-11 – Using Primary System Functions to Draft an Operational Concept	Drafted Primary System Functions and an inline definition from the INCOSE SE Handbook (INCOSE, 2015) were used to automatically draft an Operational Concept (OpsCon) as represented by 2 paragraphs and a single bulleted list describing high-level capabilities and characteristics as stated from the user's viewpoint.
UC-12 – Drafting a Plan for Eliciting Stakeholder Needs	Prompts from INCOSE SE Handbook (INCOSE, 2015) were used to automatically draft a plan for eliciting needs from real / surrogate stakeholders, gathering and analysing information, performing trade-off and validation as well as suggesting strategies for dealing with resistant / high-power stakeholders.
UC-13 – Drafting a Study Brief	Drafted Operational Concept (OpsCon) and Primary System Functions were used to automatically draft a corresponding study brief (to identify potential technology solutions, benefits, trade-offs, and recommend a preferred single viable option).

UC-14 – Drafting a Value Engineering Workshop Agenda	Primary System Functions were used to automatically draft a Value Engineering workshop agenda (covering purpose, outcomes, and process).
UC-15 – Drafting User Personas to Inform Development	x3 biographically diverse user personas were automatically drafted addressing name, age, abilities, preferences, job / professional status, family, and local information etc.
UC-16 – Drafting and Assessing System Requirements Using a Defined Ruleset	Extended inline prompts on Easy Approach to Requirements Syntax (EARS)[3] were used to automatically draft and verify a range of compliant and non-compliant requirements for autonomous grocery delivery vehicles, covering Ubiquitous, State-Driven, Event-Driven, Optional Feature, Unwanted Behaviour, and Complex forms in course. Significant iteration was required to achieve results.
UC-17 – Drafting a Risk Log	Preliminary Life Cycle Concepts and Major Stakeholder Listing were used to automatically draft candidate risks and present in a tabulated risk log format.

Conclusion

The aim of this study was to explore AI / ChatGPT capabilities and prospective applications in planning and execution of early SE life cycle processes as well as stimulate wider organisation and industry engagement. SE activities and products have been broadly modelled and demonstrated across corresponding Use Cases; from business mission needs analysis and major stakeholder identification through to drafting of Primary System Functions, Life Cycle Concepts, and rule-based requirements. Summary observations and conclusions follow:

- *ChatGPT is a present and powerful aid to human performance and productivity* as demonstrated across a range of creative / generative tasks as well as more prescriptive / technical operations. Most Use Cases translated to a few short prompts with outputs generated in a fraction of the time that it would take humans to process and complete. *Developing awareness and capability will be key to honing SE applications and managing associated change.*
- *Limits in ChatGPT training data and user prompting experience were revealed in use.* Humans and computers may reasonably be expected to struggle with more nuanced requests and syntactic rulesets. Both parties may be taught to do better over time. However, it is to be *expected that computers will learn and return results much quicker. Systems Engineers should therefore plan for adaptation and disruption of prevailing methods.* This may be seen as both an opportunity or threat depending on individual contexts and perspectives.
- At time of use, *ChatGPT seemed prone to "forget" or recast outputs over extended interactions*. This may become frustrating when working through stepped process activities that require reference to past products. Experience in prompting however has shown that this issue may be mitigated through advance naming of outputs (e.g. "draft something… we shall refer to this as X"). This issue would likely be reduced in any contextualised AI / Language Model solutions and will likely be improved in subsequent releases of ChatGPT.

[3] - Ruleset transposed from https://alistairmavin.com/ears/ *(Last Accessed 14/02/23)*.

- *Use of ChatGPT or any like commercial service is subject to associated risks and terms* (e.g. infosec, intellectual property, licensing, data transfer / storage, adversarial attacks, sources, processes, models, poisoning, malevolent / unethical uses etc). Noting pace of development, *organisations will require to identify and address these opportunities and threats as a matter of priority before deployment and active use. Systems Engineers may be expected to play a key role in facilitating associated collaboration and change.*

Artificial Intelligence (AI) has been defined as "the science and engineering of making intelligent machines" (McCarthy, 2007) and intelligence as relating to "coordination of memory, learning, and reasoning" and "the ability… to form associative links between events or objects" (Martin & Hine, 2008). *SE is inherently concerned with augmentation and automation of operations performed by humans and machines. Associated concepts, methods, and tools have been developed and applied to diverse complex and dangerous technologies over decades* (Brown, 2022). *As such, we may reasonably expect Systems Engineers to lead and prevail through contemporary developments, embracing emergent opportunities and capabilities in direct application through life cycle processes.*

Industry disruption is underway with AI applications across sectors, from weather forecasting and speech and language recognition through to self-driving cars. SL is amongst those who have already embraced AI technology (e.g. package and facility monitoring) and are committed to extending collaboration and capabilities that will drive improved decision making, automation, safety, and site remediation going forward (Selafield Ltd, 2023). Appraising and engaging industry via this paper is intended to help develop understanding and consensus on what, where, why, and how like-technologies might be incorporated into organisational workflows. *Extended collaboration with AI / data specialists is recommended to identify and manage associated use cases, benefits, risks, and change.* In the meantime, *the author commends quick and cautious exploration.*

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