Introducing the qualities and value of supersoftware — software that is itself symbolic AI.

A white paper.

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1. Executive Summary

1.1 A new epoch

LLMs mark a new epoch of artificial intelligence and demand a new epoch of software. Software that is itself intelligent. Supersoftware.

LLMs are phenomenal. Even so, they have been championed in ways exceeding their innate capabilities. More than a handful of key opinion leaders have, effectively, claimed that LLMs will do it all. Everything.

Not to detract from LLMs' demonstrable value one bit, these soundbites are viewed by increasing numbers as hyperbole. In the words of the Gartner hype cycle, we have likely arrived at the peak of inflated expectations. Either way, we don't have to argue the point but rather look to see how the market is making best use of language models. And here we find pragmatism at work, exemplified by the various ways in which LLMs are being partnered with symbolic data sources and what is somewhat affectionately called good old-fashioned AI. AI based on rules and logic. Symbolic AI.

IBM sees the hybrid approach – neurosymbolic AI – as a pathway to achieve artificial general intelligence[1]. Google DeepMind's AlphaGeometry solves geometry proofs by combining LLM-style generation with formal symbolic deduction engines[2]. Microsoft's Semantic Kernel brings a rules-based orchestration layer over LLM output[3].

Supersoftware is the perfect complement to LLMs, playing to their astonishing strengths and making up for their stark weaknesses. A neurosymbolic synergy is formed, free from the encumbrances and inefficiencies of narrower intermediating techniques.

If any of the hyperbole is ever to be realised, this synthesis will be the enabler, the catalyst. Importantly, supersoftware will allow us to govern the systematic effects of LLMs more readily, helping to ensure that the realisation of any vision is more human-centred than otherwise. This matters all the more as we contemplate supersoftware's powerful contribution to artificial general intelligence.

1.2 The product

We define supersoftware as software that is itself symbolic AI. All domains share a reactive and reflective symbolic system. LLMs interact with a system that can reason about itself — a powerful implementation of neurosymbolic AI.

Hiconic[4] is the foundational, enterprise-proven, open source homoiconic technology, stewarded as a public good. The brainchild of one of our co-founders.

Recognitive builds up and out from Hiconic specifically for the purpose of playing to the astonishing capabilities of LLMs and making up for their significant limitations.

The Recognitive platform is open source supersoftware helping everyone build supersoftware.

1.3 The technology

Technology is knowledge of how to fulfil certain human purposes in a specifiable and reproducible way[5]. It's not so much the artifacts per se but the knowledge that underlies the artifacts and the way they can be used. It's necessary then to include a rundown of the interdisciplinary knowledge we're calling on here in the last section of the paper — Our foundations.

It's the last section because readers rightly want to get to the heart of the matter — How we think about it, What it looks like in action, its commercial and societal value, and a fictitious case study illuminating the operational reality.

All hyperlinks in the main body of text are internal, often to information in the foundations section should any ideas be unfamiliar to you.

1.4 Who is this paper for?

The paper is aimed at prospective partners and investors. The paper will appeal to AI experts, software architects and engineers, CTOs and CIOs.

With the exception of the more technical aspects, it should also make sense to senior decision makers and policymakers who, by nature of their role, have experience of the transformational effects of information technology.

2. How we think about it

2.1 Intelligence, cognition, and software

Wisdom begins with the definition of terms:

- **Intelligence** is the capacity for effective cognition
- **Cognition** is the process by which information is acquired, processed, and used to figure out how to act in the environment, i.e. sensing and knowing and acting.

While cognition is too frequently associated with brains, we adopt the more expansive perspective highly regarded amongst biologists:

Living systems are cognitive systems, and living as a process is a process of cognition.

To know then is to maintain adaptive sensory-motor coordination through the relational coupling with the environment. By this definition, all software has intelligence but only often at a most rudimentary level. Nevertheless, we give ourselves the advantage of considering a very long tail of intelligence rather than subjecting our concepts to some arbitrary cut-off, and more importantly, we shift our framing here from computer science to the life sciences.

We can approach computing more usefully with the understanding that cognition requires an appreciation for how mind, body, and environment form an integrated, interactive system. Cognitive scientists talk of 4E:

- Embodied — cognition is shaped by and dependent on bodily processes
- Embedded — cognition is situated within and shaped by the broader social, cultural, and ecological environment
- Enactive — the mind and world are co-constructed by action and perception
- Extended — cognition is supplemented and enhanced by the environment, e.g. by our tools.

LLMs are qualitatively distinct from conventional software, which we'll refer to hereafter simply as software. LLMs operate over vast datasets and complex statistical relationships, enabling them to generate responses that appear fluent and adaptive, giving the qualitative impression of cognition and knowing in the much stricter sense of having been subject to conscious reflection and intentionality.

Some researchers and philosophers argue that this can't then be genuine knowing, while others describe it as a form of functional or behavioural knowledge. A focus

on what LLMs do rather than how they do it suits our purposes here. Nature selects for what works, not how it's achieved.

LLMs are bio-analogous, inspired by the design of the cortex, the part of our brain ideally suited to creativity. Software on the other hand is more analogous to the cerebellum, the system that takes that novel creation and ingrains it into the individual, enabling robust, repeatable, and flawless performance. We call on the cortex to conceive new music and choreography for example, and rely on the cerebellum for the regular and precise performance of the song and dance.

To help push home the variety of natural mechanisms in play, imagine your finger lands on the hot stove as you complete that amazing dance move while cooking dinner. A reflex action kicks in for your protection. This rapid response is managed by the spinal cord allowing you to pull away in milliseconds without the delays of messaging and your brain having a think about it. Your brain does get updated a short while later and handles the perception of pain and the process of learning (perhaps less energetic disco moves in the kitchen in future). This whole process is an example of embodied cognition.[6]

The software-cerebellum analogy isn't commensurate because the disco dance and the reflex arc both entail a much richer structural coupling of the biological system with its environment than can be attributed to software's 'sensing and knowing and acting'.

Can software step up? Can we proxy for its lack of embodiment? Software's intelligence might be crude today, but tomorrow? Nature hints that it could have more of a role to play. More value to offer. With this said, let's focus on a quality of software that isn't always front of mind.

2.2 World models

In living in the world, we all develop representations or simulations of it for reasoning and decision-making; so-called world models. It's well understood that LLMs don't 'do' world models — of chess or Othello[7] or orbital geometries[8], let alone anything approaching the complexity of social systems.

This assertion does pivot on what one considers to constitute a world model of course. A question of degree. One could argue that LLMs do form world models but inadequately, insufficiently, but that's not how we frame it. We think of LLMs in terms of "a bag of heuristics"[9] rather than world models; useful as we've all experienced, just not a world model.

This is a critical observation well worth dwelling on. As researchers from Berkeley, Stanford, MIT, Cornell, and Pennsylvania conclude[10]:

> Being able to effectively write code relies on having a strong semantic understanding (somewhat like a world model) of the entire codebase: structurally seeing how various parts of the code go together, knowing what is implemented where, understanding how the algorithms work, and keeping track of program invariants at certain program points. LLMs struggle with this global semantic understanding.

LLMs are fine during the opening stages of a game of chess because openings are very well documented. LLMs ingest these documents and use the consequent associations in their stochastic selection of the next move, but things begin to go very wrong once the opening game is concluded. The LLM doesn't have any appropriate intelligence to call on now.

The top-ranked chess engine is Stockfish. It's an example of symbolic AI often referred to as a classical engine, meaning it uses symbolic, rules-based methods combined with exhaustive search algorithms.

Another major contender is Leela Chess Zero, inspired by Google's AlphaZero. Both are neural networks, connectionist, conceptually similar to LLMs. Each learns the game entirely by reinforcement learning by playing many millions of games against itself. In other words, when there isn't any relevant information available to ingest, it creates the corpus itself.

Importantly, while self-play at scale may be possible in a non-physical realm determined by 64 squares, 32 pieces, and a rule book running to four dozen pages, your organisation is real and many magnitudes more complicated and complex. Obviously, playing millions of versions of your organisation's 'game' in advance of playing the real one is impossible.

However, this needn't be an either-or. Since 2020 for example, Stockfish integrates a neural network that works alongside the symbolic engine to assist in the evaluation of moves. This neural network is trained on extensive analysis of positions and evaluations from the symbolic engine, as well as data from games played by top players. Two artificial intelligences and human intelligence are combined.

As LLMs cannot form world models of social systems, of complex adaptive systems, might software help out? Could it be the collaborator to offer up a world model?

Software is envisaged, architected, developed, and maintained with world models in mind. The engineering team will work hard to create and work to a common world model, and inevitably each and every one working on the software brings their own subjective and slightly varying mental models to the process. Importantly:

> Almost all the knowledge and information about the design decisions the architecture is based on are implicitly embedded in the architecture.[11]

Software is the digital representation of the world model(s) that informed its design and development. Unfortunately, it doesn't render the model(s) readily legible to itself, to other software, to its engineers, or in fact to anyone or anything. The legible map (model) and the territory are separate. The map is a static description of what the system should do, while the territory is what the system actually does at runtime. The application of LLMs to software engineering has had to explore routes around this poverty.

Could the system contain a model of itself that is legible and meaningful to itself and other intelligences with which it's in relationship? Yes. Supersoftware does just that.

2.3 Reflection and homoiconicity

Self-referential systems are renowned in maths, physics, chemistry, biology, psychology, sociology, linguistics, and cognitive science. This quality is often associated with recursion — i.e. a process that repeats itself perhaps very many times — and a system's ability to inspect and modify its own structure. Together, they produce complexity with the potential emergence of higher-order meaning.[12]

In computer science, the ability to introspect and self-modify is known as reflection. When representation of both information and the processes that manipulate that information (code) are structurally identical, it's called homoiconicity, and a homoiconic system can reflect more simply and more powerfully. Its biological archetype is foundational to all living processes.

> Living is information processing … Life is both the data and the program … there is no distinction between the 'machine' and the program — both are information.[13]

You might say that Mother Nature is giving us the biggest of big hints here. (See Bio-analogy and biomimetics.)

Few technology systems are homoiconic, frustrating many aspects of how our information technology operates and interoperates today. The Lisp programming language is a rare and marked exception, renowned of course for its profound and enduring relationship with the field of symbolic AI.[14]

However, while Lisp is the poster child of homoiconicity, it only manifests the quality syntactically, i.e. relating to the arrangement of its data structure (s-expressions). A symbol becomes an operation only when the interpreter expects it to be one in that specific context, i.e. structure is contingent upon the executor's local understanding. Inspired by the use of the prefix in biology, we call this endo-homoiconicity.

By contrast, exo-homoiconicity is achieved with shared canonical type-safe structure and declarative reflection enabling types and properties to declare their own potentiality. The functions of the proteins essential to life aren't defined by some external interpreter; their canonical, physical shape is their potentiality. Without this quality, there would be no life as we know it.

Our team members have been working on this broader and deeper appreciation of homoiconicity and reflection since 2010. Enterprise-proven in Fortune Global 500 companies in an adjacent context, it's open sourced as of December 2023.

The technology brings homoiconic, reflective, polymorphic modeling to any domain. It establishes homoiconicity at a higher level than the typical association with programming languages, and provides the crucial technological basis for portable addressability of functions in distributed, decentralised, panlingual, and artificial intelligence environments.

The Recognitive platform builds out and up from this technology for the purposes of creating and evolving supersoftware in partnership with LLMs.

2.4 Software and LLMs in collaboration

Are LLMs more able to 'work with' programming languages that are homoiconic versus nonhomoiconic?

There's a compelling argument supported by emerging research that homoiconic languages (e.g. Lisp, Scheme) could offer inherent advantages for LLM 'understanding' and code generation. Here are two recent perspectives.

> [Lisp's] hallmark feature — homoiconicity, or the uniform representation of code and data — naturally complements the capabilities of large language models, which benefit from easily parseable and manipulable structures. … Lisp's uniform parenthesized expressions reduce both cognitive and computational load — allowing language models to focus more on semantic content than on syntactic correctness.[15]

> [Lisp's] unique capacity to represent and manipulate symbolic information provides a distinct advantage for certain AI tasks. … LISP's core strengths in symbolic manipulation and metaprogramming uniquely position it to address the challenges of next-generation AI, such as the growing need for explainable AI and more sophisticated agent architectures. The potential for LISP to play a role in meta-programming for LLMs and AI agents presents a promising new direction for its application in the evolving AI landscape.[16]

LLMs are designed to master the statistical, semantically-rich, and structurally ambiguous world of natural language. When we apply these models to code, we hit a fundamental mismatch.

Lisp's endo-homoiconicity offers only flat syntax whereby meaning is opaque and contingent on the local context of an interpreter. While an LLM can learn to imitate the syntactic patterns of S-expressions, it cannot truly grasp their verifiable meaning because that meaning doesn't exist until runtime.

Recognitive's new exo-homoiconic foundation provides the explicit, verifiable ground that's been missing. The expansive self-referential structure helps form a denser and more interconnected web of syntactic patterns useful for token prediction than for nonhomoiconic languages or indeed for endo-homoiconic programming languages.

The LLM's role becomes translating ambiguous human intent into this precise structural grammar, finally enabling a safe and powerful synergy between statistical intuition and logical reasoning.

In some ways, Recognitive might be considered Lisp's precocious grandchild — it's picked up a type-system and schemas down the family line, and disentangled exo-homoiconicity is the new trait. Unlike its grandparent, Recognitive imbues software with a deep, predictive understanding of its own structure. It can introspect and formally validate a proposed code change without running it, and reason about relationships, and yet its talents don't stop there.

Modern software systems involve far more than application code, e.g. configuration files, data pipelines, API definitions, database schemas, dependency manifests. Everything in a supersoftware system is homoiconic, acquiring a holistic reasoning capability in the process. This capability is most succinctly expressed by the following fictitious example of supersoftware's 'train of thought' articulated in partnership with a LLM:

> The LLM has proposed changing the signature of this function, and we've all agreed. My model shows this function is exposed via our public API. Therefore, this change is not just code; it is a breaking change to our API contract. We must plan to version the API, update the documentation, and notify our partners.

Supersoftware is a cognitive organism. It's the canonical world model of the organisation and its primary enactment, in constant collaboration with the organisation's other intelligences on both fronts. In light of these qualities, let's broaden and deepen the question at the top of this section.

Are LLMs better able to generate more informed, accurate, explainable, timely, and contextually rich responses when interacting with systems in which all domains are homoiconic and reflective compared with systems that don't have this quality?

Yes. It stands to reason.

A paper co-authored by a connectionist pioneer found that the way a computer understands simple tasks and the way it understands how to learn new tasks have a lot in common, and that for such an application “our homoiconic approach significantly outperforms a nonhomoiconic baseline”[17]. This suggests that if an LLM could process coding problems and language constructs within such a unified, self-referential framework, its ability to understand code deeply and generate novel, correct solutions, especially for unfamiliar problems, will very likely be enhanced.

Supersoftware will allow LLMs to develop a more fundamental 'grasp' of programming logic, much deeper than surface-level pattern matching. An LLM interacting with a system where all domains — code, data, schema, configuration, APIs, etc. — share a unified, reflective, homoiconic symbolic system will have access to a profoundly richer and more integrated contextual ‘understanding’, leading to significantly superior responses across all dimensions.

Such an infrastructure transcends traditional retrieval-augmented generation (RAG), whereby an LLM might query a separate knowledge base or graph representation of code. We have a LLM (connectionist AI) interacting with supersoftware (symbolic AI), enabling such things as:

- **Introspection and status reporting**. The system can answer questions about its own current state (“What's the current configuration of service X?”), structure ("What are the dependencies of code module Y?"), or definitions (“What's the schema for data type Z?”)
- **Consistency checking**. It can reason about the internal consistency between its parts (“Is this API call signature compatible with the current API version definition?”, “Are all dependencies for this deployed code module met?”)
- **Impact analysis**. It can infer the potential consequences of a proposed change ("If I modify this part of the schema, which code modules, APIs, or data instances will be affected?")
- **Explanation of behaviour**. It can trace how a certain state was reached or why a component is structured a certain way by examining its models, rules, and history (“This API endpoint behaves this way because it's implemented by this code, which was governed by these configuration rules at the time, and processes data defined by that schema.”)

For informed and contextually rich responses, an LLM can retrieve not just isolated facts but the interconnections between, for example, a piece of data, its defining schema, the code that manipulates it, the configuration affecting that code, and the API that exposes it — all represented consistently. The supersoftware provides real-time information about its own state and structure, ensuring timely and relevant context and analysis. Accuracy is greatly enhanced because responses are grounded in this deeply interconnected, verifiable symbolic truth, where relationships are explicit not just inferred.

	ROLE	VALUE	BLINDSPOTS / LIMITS
Traditional scientific and engineering intelligence (systematic thinking)	Breaks problems into discrete parts, rigorously analyses and optimizes them, ensures reliability, correctness, and efficiency.	Provides precision, quantitative rigor, and practical, tested solutions within well-defined boundaries.	Too often overlooks human, emergent, and relational dynamics.
Systems thinking intelligence (holistic / ecological thinking)	Making sense of things as interconnected wholes and relationships, with emphasis on feedback loops, emergent behaviours, and unintended consequences.	Guides strategic foresight, identifies systemic risks and opportunities, and helps avoid myopic optimisation that harms overall system health.	Can resist reduction of action if overly abstract.
Other human intelligences (emotional, social, creative, practical, etc.)	Brings context, intuition, cultural, ethical, and emotional insights and capabilities, and a diverse sense of values and priorities.	Anchor solutions in human realities, social dynamics, narratives, motivations, and ethical frameworks that pure engineering or AI may overlook.	Susceptible to bias, subjectivity.
Connectionist AI (LLMs, forms of neuro AI)	Processes and generates natural language, infers unstated context, abstracts across domains, supports creative problem exploration and dialogue.	Bridges human and machine communication gaps with conversational UI, surfaces latent insights from unstructured data, and augments human creativity.	Lacks world models, grounding, explainability, intent, values.
Symbolic AI (rule- and logic-based)	Encodes explicit domain knowledge, formal reasoning, and decision rules; can explain and justify decisions.	Enables trustworthy decision automation where rules are well known, compliance is critical, and transparency is required.	Potentially brittle in open-ended contexts.

Table 1: Categorisation and comparison of the intelligences discussed here.

2.4.1 Enabling active inference

The core insight of active inference is profound, yet a primary challenge in its digital application lies in the nature of the model itself. For an AI to engage in active inference, it cannot rely on static representation. The generative model must be constitutive of the agent, an operational substrate that can be acted upon and iteratively refined through the 'lived' coupling of agent and environment. Minimizing free energy (a measure of the gap between what the agent expects and what it actually encounters) thus demands a model that is dynamic and mutable from the outset; an innate quality of supersoftware.

2.5 Combining intelligences

As this paper is prompted by innovations in information technology, we begin with a type of intelligence most closely attributed to science and engineering. By way of necessary counterbalance to such analytical rigour, we follow with a type of intelligence that seeks meaning in patterns rather than in the precision of pieces, and is in fact increasingly embraced in science and engineering. We then have a catchall for all other types of human intelligence followed by two categories of artificial intelligence.

Recognising these different strengths and weaknesses is a first essential step to guiding their optimal combination. And then, per the insights of cybernetics, the combination and integration of intelligences demands recursive and reflexive interactions[18]. Or to put it more plainly, intelligences take turns influencing each other, maintaining and developing a meta-intelligence in the process.

Obviously, the artificial intelligences are the newest forms opening up the design space here. While this is not the place for a potted history, we will recognise a trend since the advent of commercial LLMs to consider the connectionist approach so superior to symbolic AI as to render symbolic AI redundant. Indeed, human intelligences are too often swept away in the same breath. We do not subscribe to this view of the world as should be evident by everything in this paper so far. LLMs will never do it all. Intelligence is always collaborative, and it appears LLM vendors' actions increasingly corroborate as much.[19]

LLMs clearly excel at natural language processing and realise the long-held goal of conversational interfaces.[20]

> The way you accomplish tasks with a product — what you do and how it responds — that's the interface.[21]

In the context of a conversational interface, the product is fronted by a LLM chatbot and the task is carried out by prompting it for information or to do something. The

product may be an integrated development environment (IDE) for the task of software engineering (see AI-augmented software engineering).

2.6 Pulling it all together

Human intelligence has always included emotional, social, creative, and practical dimensions; intelligences with tens of thousands of years of history. What we now call systematic thinking emerged much later, codified during the Enlightenment into the dominant scientific and engineering paradigms. And while systems thinking was formally developed last century, its core intuitions have ancient roots in indigenous and philosophical traditions that were largely displaced by reductionism only to be revived as reductionism's severe shortcomings became more obvious to more and more people. That's a quick-fire way to reassert that all forms of intelligence have their role to play.

As discussed earlier, intelligence is a capacity for cognition. The overall capacity is increased when a variety of intelligences are combined such that their respective strengths make up for their respective weaknesses, and we can now channel our understanding of everything above to describe the transformational effect.

2.6.1 Complexity with simplicity

This paper presents a new choice in the contexts of LLMs and software interacting: software can remain largely unreflective, or we can enliven it as symbolic AI to become an equal partner with LLMs. The latter is more straightforward than alternative ways to get LLMs and software to play nice. It's built-in, not bolted on, direct rather than intermediated.

Vitally, supersoftware supports the requisite complexity with much greater simplicity.

2.6.2 Embodied and embedded cognition

Software today is deeply embedded in the organisation's environment, defining the landscape, the pathways, and the constraints in good part. But it's not a cognitive embodiment; more inanimate prosthesis than animate limb.

Supersoftware couldn't feel more different. It's an active, self-aware, reflective, and self-modifying part of the organisation's cognitive body, invoking biological analogies such as feeling and healing. Supersoftware can communicate its internal, reasoned state to LLMs directly, symbolically, and to us humans symbolically, and in natural language via a LLM. Supersoftware co-evolves as and with the organising, as and with the organisation's economic, social, technological, and environmental contexts.

2.6.3 Extended cognition

To say that software is a tool and supersoftware is an AI tool is to miss the fecundity of the interweave of intelligences here. Supersoftware is a new form of collaborative extended cognition. It's the difference between a tool that extends your memory — e.g. a CRM system — and a collaborative partner that extends your capacity for reason.

2.6.4 Enactive cognition

Software enacts business processes deterministically and rigidly. Supersoftware encompasses the co-construction of knowing and the world through the continuous loop of perceiving the organisational environment and acting upon its own code.

Imagine the collaboration of intelligences of which supersoftware is part perceiving a change in its world, perhaps a new security threat or regulatory requirement (see the Fictitious case study). In that collaboration, supersoftware modifies its own structure and so simultaneously co-constructs its own symbolic 'understanding' and its world.

2.6.5 World model and meaning

The vast majority of organising entails software. With supersoftware, the corresponding world model *is* the software in good part, made dynamic, real-time, and legible to all intelligences in the mix. Reflecting it back at them. Similarly, supersoftware is the territory and often the medium by which decisions reached by the combined intelligences are implemented.

We can consider four parties in the organising: software engineers, everyone else, software, and LLMs. With supersoftware in the mix, all four parties are palpably intelligent and their combination all the more so. All four parties 'speak the same language' with shared meaning in the models. All four parties can discuss the models in natural language with the necessary subjectivity and contextual relevance, supported by the precision of the underlying model grammar.

The shared 'language' allows software itself to validate that any proposed change adheres to its core, provable structure. Intent is made a living, computable part of the system. What were once merely external prompts become active and formally modeled constraints that directly guide and bound the AI's scope.

2.6.6 Governance and control

The LLM is no longer an untrusted external tool in the contexts of software design and development, but an integrated creative partner. The combination of LLM and supersoftware is a powerful implementation of neurosymbolic AI. The readiness

with which the system can ascertain what should be, what is, and how best to close the gap meaningfully and accountably, transforms the potency and cogency of the associated governance processes. Being built-in rather than bolted on, being direct rather than intermediated, the system is self-aware and capable of far greater self-control.

2.7 AGI

AGI is characterised by a fluid intelligence able to rise up to challenges it hasn't seen before[22]. The value of Recognitive doesn't pivot on it making a contribution to AGI. Nevertheless, it does.

2.7.1 By evolution

With mass adoption of Recognitive and innate to its biomimetic qualities, we expect the very natural emergence of new architectural structures in just the same way biological systems evolved new cell types, organs, and nervous systems to achieve higher levels of complexity; albeit over a significantly compressed timeline. As degrees of reflection increase and structures proliferate, LLM model size reduces significantly and next-level capabilities materialise, i.e. a potential new form of artificial intelligence emerges, plural and decentralized by nature.

2.7.2 The grounding problem

A major barrier to AGI is LLMs' inability to reason reliably or ground their outputs in a verifiable model of reality; the grounding problem[23]. Without this connection, AI systems process patterns of symbols without grounding them in lived perception or embodied reality. True general intelligence likely requires embodiment, i.e. the ability to interact with and learn from a real environment.

Supersoftware grounds LLMs with the world through us (see World model and meaning).

2.7.3 Intermediary stratas

There isn't a simple jump from neural firing patterns to explicit symbolic thought in biological systems. There are intermediary strata — embodied, social, and ecological dynamics.

Nevertheless, the dominant mode of neurosymbolic AI research, specifically the elicitation of symbolic knowledge from neural networks in pursuit of tight neurosymbolic integration, assumes such strata can be abstracted away. While this is wholly aligned with computer science methodology and has the advantage of

being more readily formalised, and while it may also best serve narrow pragmatic goals, it's sub-optimal in the context of combining human and artificial intelligences naturally and powerfully.

Recognitive addresses the intermediary strata between raw neural processing and formal logic. That stratum is us, effecting a tight and grounded cognitive loop with the technological system.

This creates a powerful feedback loop best described by the concept of enactive cognition. Rather than the AI simply being a tool we command, we have our minds, the world, supersoftware, and LLMs co-constructing one another through cycles of action and perception.

2.7.4 Program synthesis — a foundational component of a form of AGI

The vista here is captured well on the website of new startup[24] founded by a leading AI expert:

> The path to AGI is not through incremental improvements to existing methods. The problems with deep learning are fundamental and cannot be addressed superficially. It's time for a new paradigm. The good news is that we know what it is: program synthesis.
>
> … Instead of interpolating between data points in a continuous embedding space, program synthesis searches for discrete programs, or models, that perfectly explain observed data. This allows it to achieve much greater generalization power with extreme data-efficiency, requiring only a few examples to learn. … We believe program synthesis and deep learning are equally important.

Program synthesis is a class of techniques able to generate a program from a collection of artifacts that establish semantic and syntactic requirements for the generated code. Specifically in AGI contexts, it's the process by which an intelligent system builds explicit, reusable programs to solve new problems from minimal data rather than relying on pattern-matching from massive datasets.

As an advanced program synthesizer, Recognitive is a foundational and catalytic component of this form of AGI. LLMs ingest and generate supersoftware with a far deeper and more useful 'grasp' of its intent than is possible with a corpus of conventional code, and supersoftware can be instrumented and evolved dynamically without ever needing to be recompiled or redeployed.

Recognitive aligns perfectly with this 'new paradigm' of program synthesis. We share the vision with a significant qualifier: any program synthesis is very much more likely to serve the pursuit of AGI as and when all domains share a

homoiconic, reactive and reflective symbolic system. More than a concrete embodiment of the vision, Recognitive channels the deep natural processes that inform the evolution of cognition. The paradigm may be new in computer science but is otherwise as old as life itself.

	ROLE	VALUE	BLINDSPOTS / LIMITS	EXAMPLES
Graphing Techniques	Uses graph-based representations to model relationships between software components and their interactions.	Enhances understanding of dependencies and relationships in software architecture.	Complexity in graph construction; may require extensive data.	CAST, Apiiro, Neo4j
Scripting, Automation, and Orchestration	Enables custom scripts that allow LLMs to interact with development environments and tools.	Streamlines workflows and automates repetitive tasks, improving efficiency in development.	May require technical expertise; limited to the scope offered by each tool. Only has secondhand knowledge of the software.	Tessl, GitHub Actions, Microsoft Semantic Kernel, n8n
Fine-Tuning and Transfer Learning	Adapts LLMs to specific programming languages or frameworks through targeted training on relevant codebases.	Improves accuracy and relevance of code suggestions and documentation generation.	Requires substantial domain-specific data; risk of overfitting.	OpenAI Codex, Hugging Face Transformers
Prompt EngineerinG	Crafts specific prompts to guide LLMs in generating relevant code snippets or documentation.	Enhances the quality of code generation and documentation, making interactions more effective.	Effectiveness can vary; may require iterative testing to refine prompts.	PromptBase, Replit
Reinforcement Learning from Human Feedback (RLHF)	Uses human feedback to train LLMs on coding practices and software development standards.	Improves alignment with developer intentions, leading to more satisfactory code suggestions.	Dependence on quality of feedback; may not generalize well across contexts.	OpenAI's ChatGPT, Anthropic's Claude

Table 2: Comparing approaches to improving LLM ‘understanding’ of software and assisting their contribution in developing and maintaining software.

3. What it looks like in action

3.1 Transforming software engineering

The core challenge in software engineering is identifying patterns and abstracting them into reusable routines to reduce entropy. Nevertheless, traditional high-level languages impose structural complexity that hinders this process, especially when abstraction goes beyond domain-specific logic. Reflection in Java for example attempts to offer flexibility but remains inefficient due to the arbitrary diverse nature of class structures — methods, parameters, return types, static and instance members, and more.

Reflection becomes trivial when entities follow a strict structure — typed properties that are primitives, collections, or references to other entities. The reduction to enumerating properties eliminates unnecessary complexity while allowing for highly efficient, domain-agnostic algorithms such as serialization, cloning, visitor-based traversal, and persistence.

The simplicity of this paradigm makes it particularly powerful in networked applications and distributed software architectures where state synchronisation, data marshaling, and distributed processing require low-entropy, predictable structures.

Since every entity follows a well-defined schema, networked services can exchange structured data efficiently, reducing the need for verbose conversion layers or complex adaptation logic. By minimising entropy, the system remains resilient, extendable, and easier to reason about.

And then things start to get really interesting. The relationship between software and LLM is transformed, our primary focus here of course, and non-von Neumann ideas can overcome the integration challenges of significant architectural heterogeneity, data representation, communication, and instructions execution[25]. A post-von Neumann network-based computing architecture doesn't just become possible but likely.

3.2 AI-augmented software engineering

While LLMs promise a revolutionary leap in the velocity of software development, the promise remains largely beyond reach, all the more so for organisations operating in high-assurance environments.

Generative AI's lack of understanding of architectural integrity, and its inability to form and maintain a world model of the enterprise and its software, make it unsafe.

LLMs produce technical debt and violations of the system's fundamental architectural invariants, governance policies, security policies, and resource constraints at unprecedented rates. Despite claims of 2x, 5x, and even 10x productivity gains, it appears engineering productivity actually declines[26], although it should also be said that the subject remains contentious.[27]

Various attempts are being made to resolve some of these problems, see Table 2.

Further to the blindspots / limits listed for each, it's noteworthy that they are all interventions. Intermediations. Translations. Complications. Some are more probabilistic than engineered assuredness. All assume software remains comparatively dumb.

Few engineering teams, trending to zero in high-assurance software contexts, would be content leaving an LLM to anything at all. As one software engineering lead put it, imagine a typical scenario of a 20-strong engineering team bringing on 1 intern. Now imagine every engineer partnering up with an AI dev tool. They now have 20 interns to look after. And it might start to feel all the more challenging as and when urgencies demand engineers are less than thorough in supervising their most eager charges.

Reliance on LLMs for maintaining and developing software produces an awkward and risky alliance falling far short of the desired and indeed required symbiosis. Recognitive doesn't just address these problems, it transforms the paradigm of software development.

3.3 Meaningful modeling

We apply homoiconic data modeling to strongly decouple data from semantic and technical domains, e.g. persistence, exchange formats, protocols, and event-sourcing. Normalized models are the pivotal interface for data, configuration, functionality, and errors, and all models are extricated from technological aspects such as processing code or programming languages, consciously breaking with OOP (object-oriented programming) encapsulation in favor of expert late binding, as we find in nature (see Genetics).

Models can be forked, shared, and merged. Vitally, in light of our biomimicry, such diversity of contextual modeling affords variation, selection, inheritance, and speciation, which together constitute the neo-Darwinian understanding of evolution. The models are analogous to the organismic genotype.

Such an approach begins to move us on from the struggles of the semantic web to the realisation of the meaningful web. Semantic here refers to the precise definition of words and their relationships within a specific language system; the objective technical aspects. Meaningful relates to the overall significance and implications of something, often involving subjective (i.e. human) and contextual interpretation.

You might say the semantic web is technical and totalizing whereas the meaningful web is contextual, plural, natural, human.

Subjectivity and contexts are celebrated for both domain agnostic and domain specific applications, yet a strict dedication to reflectivity maintains model inter-relatability.

3.4 Grammar

The grammar is a convenient syntax for text-based formal model declaration. It's used to declare the model identity, model dependencies, and model types with their properties and constants. Metadata may be added to the model's structural elements (model, type, property, constant), both eagerly and lately when extending a model. The grammar can declare any model, and starts with the model that represents the grammar itself.

The grammar necessarily describes any data graph of any model, making it expressive in terms of model structure and generic when it comes to describing complex metadata instances. Data types can have intricate deep structure.

All expressive syntax elements allow continuation on a generic level (like the metadata) in order to keep the format open beyond its well-known structures.

```
entity Greet extends ServiceRequest {
String name

String eval()
}
```

3.5 IDE

The IDE is an application or plugin to existing IDEs for model designing, either with the grammar or graphically.

The IDE helps with syntax coloring, AI-assisted code completion, hyperlinks to follow the referential identifiers in a model to its declarations, and modularization. The graphical design helps with convenient navigation and extension of the graph describing the model.

The IDE helps to refactor models in various ways. It dynamically resolves model dependencies and is able to pull / push designed models to repositories.

With the advent of natural language programming, our IDE will include an AI agent available to the AI agents of all variety of IDEs, facilitating the masterful application of our technology in those environments.

3.6 Repository

The repository stores models in their native, grammar-defined form and makes them dependable for the IDE or concrete programming languages. It has ‘faces’ to view the dependable deliverables in a language specific form such as NPM, Maven artifacts, Ruby GEMs, etc. And a ‘face’ designed for human and artificial intelligences with rating, description, and comment metadata.

3.7 Panlingual exchange format

In order to store and transport type-safe model data referentially, comparably, polymorphically, and efficiently, and so it may be deep nested and streamable, we offer an upgrade from JSON, YAML, and XML with a scalable exchange format supporting:

- Proper base types with their efficient literal syntax:
  - string, boolean
  - various number formats instead of just number
  - time types (data, time, datetime, etc)
  - binary data
- Native references — backward and forward
- Includes
- Placeholders
- Type inference, type explication
- Reference pools of values to maintain a flat syntactical structure, even when representing potentially deep, complex data graphs (avoiding indentation hell).

Where a panlingual exchange format helps:

- Data integration — reducing the "integration tax" that consumes up to 50% of IT budgets
- Multi-cloud and multi-domain consistency — eliminating need for custom normalization across cloud providers and services across the overall system

- Interoperability — enabling better tool integration and data sharing.

By way of a comparison, Google's Protocol Buffers allows data and function structures to be serialized in a domain-bound way that optimizes them for network transmission across diverse computing environments. Recognitive achieves much more. Our polymorphic domain-agnostic models assist transmission but also function, persistence, reflection, metadata, presentation, configuration, and errors.

The panlingual exchange format will be considered a significant upgrade from model context protocol[28] (MCP).

ETL pipelines are managed by data teams, which are often siloed under a Head or VP of Data and include their own dedicated engineers and product managers. Even when these teams operate efficiently, the rest of the company must integrate with or around their work. Traditional ETL processes follow static, predefined rules: data engineers write code to transform data from point A to point B, while data analysts interpret what those engineers have implemented to understand what stakeholders want to know.

As supersoftware treats transformation logic itself as data:

- Rules can be dynamically modified and composed
- The same framework that processes your business data also processes the transformation rules

FEATURE	LISP	PYTHON	PROLOG	JAVA	RECOGNITIVE
Paradigm	Functional, Procedural, Object-Oriented	Multi-paradigm (Imperative, Object-Oriented, Functional)	Logic Programming	Object-Oriented, Imperative	Modeled, Homoiconic, Polymorph,Functional (Expert), OOP
Syntax	Parenthesized (S-expressions)	Indentation-based	Rule-based	C-style	Property Access, Flexible Object Literals (wiring)
Typing	Dynamic	Dynamic	Dynamic	Static	Primarily static
Memory management	Automatic (Garbage Collection)	Automatic (Garbage Collection)	Automatic (Backtracking)	Automatic (Garbage Collection)	Automatic (Garbage Collection)
Meta-programming	Powerful macro system, Homoiconicity	Limited	Limited	Reflection	Model / Data Reflection, Homoiconic self-instrumentation

FEATURE	LISP	PYTHON	PROLOG	JAVA	RECOGNITIVE
Community & libraries	Smaller, focused on symbolic AI	Large, extensive libraries for various AI tasks	Smaller, strong in logic programming	Large, libraries for general AI and big data	Holistic and versatile libraries for domain agnostic model operations
Performance	Generally faster	Generally slower	Can be efficient for logic-based problems	Robust performance	Robust performance + reflection boost for domain agnostic operations
Learning curve	Steeper	Easier	Moderate, requires a different way of thinking	Moderate	Moderate
Symbolic reasoning	Excellent	Limited	Excellent	Moderate	Excellent regarding all homoiconic modeled features
Machine learning	Historically used, integration efforts ongoing	Dominant, extensive libraries	Less common	Growing with libraries like Deeplearning4j	Well-suited via normalized models and homoiconicity
NLP	Strong historical presence	Widely used with libraries like NLTK and spaCy	Well-suited for parsing and understanding	Used, but less dominant than Python	Well-suited via normalized models and homoiconicity
Expert systems	Historically significant, still used	Possible, but less natural	Well-suited	Possible	Well-suited via its normalized models and expert bindings. Homoiconicity and expert systems go hand in hand.
Scalability	Can be scalable, Clojure on JVM offers good concurrency	Scalable with appropriate frameworks	Depends on the implementation	Designed for scalability[31]	Designed for scalability

Table 3: Portraying Lisp's comparative strengths in the context of AI programming, reproduced from Quantum Zeitgeist magazine with the addition here of a column for the Recognitive language.

- Operations become auditable, portable, and replayable across your entire stack
- You get automatic format manifestation rather than manual pipeline coding.

The integration tax is eliminated because transformations become self-describing and composable rather than hardcoded pipelines.

3.8 Programming language

It's worth stating up front here that adoption of Recognitive is far from contingent on the native language, which is just as well given that language adoption takes many years. Rather, Recognitive is initially embedded in developers' familiar environments, e.g. Java, TypeScript, Python, Rust, Go.

The programming language is as specified as possible based on the model system. In other words, models define the programming language and keep it normalized for common processing by all variety of tools. The language's essential models include:

- instruction-model
- module-model
- package-model (to identify deliverables and their dependencies).

The programming language has expressive grammars for the most important models, and strong literals to reference its own structures for reflective, generic programming (self-instrumentation):

- this method
- this class
- this instruction
- this module
- this field.

The programming language handles dependencies automatically to avoid version clashes. It distinguishes between dependencies for module-internal requirements and dependencies for module-external sharing.

How should it stack up?

Table 3 portrays Lisp's comparative strengths in the context of AI programming, reproduced from Quantum Zeitgeist magazine[29] with the addition here of a column for the Recognitive language.

4. Better

How will Recognitive improve things? For example, how might it contribute to human flourishing and to our abilities to live in harmony with all other life on Earth? More pragmatically and imperative in terms of adoption, what's the business value? As the latter affords us this opportunity, we'll start there.

4.1 Business value

Organisations exist to create value that could not be created otherwise. Value for customers. For shareholders. For employees. Partners. Suppliers. Citizens. Any lingering idea that an organisation is defined by its payroll is relegated to the 20th Century where it belongs. An organisation is reliant upon all these participants to sustain and grow its ability to create value, and if the participants do not find the value they're looking for, they'll seek it someplace else.

To avoid invoking hard boundaries, we find that thinking in terms of organising rather than organisation better reflects this reality.

Definitionally, organising involves cognition and intelligence: the means and capacities by which your organisation acquires information, processes it, learns, and uses it to figure out how to act in its market. While it might be expressed in all kinds of ways, the ultimate question in every boardroom, at the heart of every strategy review, and permeating every management conversation, is:

> How might we organise better to create more value today and tomorrow?

For clarity, per living systems theory, we take organising to include being inventive and experimental, responding creatively when circumstances inspire and indeed require.

4.1.1 IT-business alignment

IT-business alignment is the degree to which business and IT depend on one another and share their domain knowledge to achieve a common goal.[31]

Recognitive has immediate value in the IT context, as should be apparent to any reader of this paper, yet its deeper transformational value demands structural and cultural adaptation. The challenge is so stark that much research into the topic presumes IT and the business to be diverse and separate organisational areas[32], which is far from a good start. Business leaders have to involve IT leaders. Business and IT professionals have to collaborate in defining problems, in setting goals, and in determining what to do. Recognitive is the enabler.

The rewards are substantial in terms of agility, relevance, effectiveness, cooperation, competitiveness, and overall business value.

We refer to the diligent integration of human and artificial intelligences in pursuit of the purpose(s) at hand — an integration contingent upon supersoftware in light of the limitations of LLMs — as superorganising.

4.2 Social impact

This topic is of course much bigger than one section of a white paper but it's important to at least point in the direction of a more extensive future exploration.

Technology is never neutral. Its conception is always grounded in a set of contexts, worldviews, values, and ends in mind. Technologies encode practices and values into the societies that adopt them.[33,34]

4.2.1 Our design values

Value Sensitive Design[35] (VSD) engages "human values in the design of tools and technology to support human flourishing". A value is "what is important to people in their lives, with a focus on ethics and morality." It considers individual, group, and societal levels of analysis and observes that "in the complexity of human relations, values sit in a delicate balance with each other. This framing positions designers and researchers to emphasize moral and ethical values, but to do so within the complexity of social life, and with recognition for how culture and context implicate people's understanding and experience of benefits as well as harms and injustice."

The Recognitive team holds these values:

- We value digital systems that can be shaped by everyone, individually and collectively
- We value digital technologies that assist communities in their implicit and explicit sense-making
- We celebrate and nurture what is essentially human over the essentially technological, yet fully embrace technology's potential to promote human flourishing.

For example, taking each value in turn:

- With Recognitive's emphasis on readily understood symbolic models and a conversational interface, all stakeholders can engage directly with and in the system rather than via detached representations of the system of varying veracity

- The platform's symbolic reasoning core is designed to surface logical inconsistencies and hidden assumptions, providing a concrete foundation for collective deliberation
- Human intelligence is foregrounded when it should be.

If your idea of better coincides with these values, then the conception, design, and development of Recognitive is off to a good start. But what about supersoftware developed with Recognitive? This has to be open to VSD by definition. Let's take a quick tour of accountability, decentralization, cooperation, and the vision of social cyborgs.

4.2.2 Accountability

In light of its inordinate advantages, supersoftware will eventually supplant conventional software. How then might its use be subject to societal governance? i.e. nudging supersoftware-based systems towards supporting if not in fact manifesting societal good.

Accountability (see On governance) is a core concern to the cooperative talents of the human species. It's a natural process albeit one that demands scaling with scale. Supersoftware elevates governance and enables metagovernance, i.e. emphasising coordination and cooperation between different systems of governance, making values and effects legible, and empowering community participation in the process.

With the benefit of determinism, ethical guardrails and failure modes can be modeled and made widely available, and their adoption made an auditable quantity. The Fictitious case study portrays verifiable compliance with a new regulatory requirement, and verifiability applies whether the system property in question is a legal requirement or any other kind.

4.2.3 Decentralizing

Concentrations of power must be avoided whenever possible. Yet of course LLM training is a specialist undertaking demanding very deep pockets, economics that inevitably concentrates power.

By contrast, the cost of developing supersoftware and the cost of configuring the use of supersoftware should be less than for conventional software today making it accessible to all and infinitely customisable. Supersoftware keeps LLMs and so LLM vendors in check in decentralized systematic contexts. While it does not address the problematic power concentration directly, it curtails potential abuses.

4.2.4 Social cyborgs

No-one reading this can be described or understood solely in terms of the biological, psychological, and social. You are bound together with information technology. Your sensing is digitally augmented. Your sense-making and cognition are digitally augmented. Your acting in the world is digitally augmented. These are definitionally essential living processes. You are then cyborg.

There's no doubt we can massively improve and cohere and grow our cyborginess, not least by a dedication to our innate social qualities. We refer then to social cyborg, and that's social in the true sense of the word — i.e. the nature of human interaction — rather than the way in which the word has been co-opted in web2.

Supersoftware will help realise social cyborgs with the autopoietic concept of organisational closure. This is compatible with the hopes of those championing so-called 'self-sovereignty' without the contradictions and unnatural implications that idea brings with it – autonomy in nature is always relational. A topic for a future paper.

4.3 Cooperation at scale

Cooperation may be considered within business value, and within social impact, and also as a connector between these two realms as if perhaps they are indeed one and the same.

With unprecedented interoperability (see Panlingual exchange format), supersoftware enables a collective intelligence of supersoftware-based systems. We can consider a 'hyperorganising' including the integration of non-human, non-artificial intelligences and / or proxies.

5. Fictitious case study

This fictitious case study provides a vignette on the early operational reality of supersoftware which can get lost in a paper describing the big picture vision.

5.1 Introduction: agility vs. assurance

Adapt Financial is a leading financial services institution with over 10,000 employees and a global technology team of 800 engineers.

The company's core trading platform, Odyssey, is the integration of supersoftware (i.e. developed with Recognitive) and the company's LLM of record. (This case study will now refer to Recognitive / supersoftware and the LLM accordingly rather than Odyssey as an integrated whole.)

The technological architecture and approach is central to the company's strategy of maintaining elite performance and high-assurance security in a hyper-competitive, highly regulated environment. Errors can cost millions and yet responsiveness is a fundamental competitive edge.

A new regulatory mandate was issued in Q1 2028, Directive 2095-08B, requiring all institutions to log and report transaction finality latency for a specific class of over-the-counter (OTC) derivatives. The directive came with a tight deadline of 30 days.

5.2 Understanding: from prompt to formal constraint

5.2.1 Formalizing the objective

Instead of a human team beginning weeks of manual code archaeology, Adapt's lead architect presented the text of Directive 2095-08B directly.

The text is not treated as a simple prompt for a generative model. Rather, the neurosymbolic system (Recognitive + LLM) parsed the regulatory language and translated it into a new, formally modeled constraint on its own behavior. The requirement to "log and report transaction finality latency" became a verifiable constraint added to its existing set of operational goals and constraints.

This act turned a piece of external text into an intrinsic, bounded problem space guiding all subsequent actions.

5.2.2 Contextual analysis

Recognitive queried its own structure, identifying the key components involved: the `Executor` module and the `ChronoBus` message bus.

It passed this context — the new formal objective combined with its own architectural model — to the integrated LLM with a clear instruction:

> Propose modifications to satisfy this new objective.

5.3 Planning: immune system and impact analysis

5.3.1 Plan A

- The LLM proposed an initial course of action: a simple logging approach.
- Working to each other's strengths, the Recognitive + LLM combination concludes that this is a naive approach. Attaching a synchronous logger to `Executor` would introduce a variable 5-8 millisecond latency during peak trading volume, violating a core platform SLO.
- Rejected.

The core symbolic logic acts as a biological immune system, rejecting the idea deterministically without a human needing to be in the loop. Nevertheless, the Lead Architect opted into the train of thought:

> PROPOSAL REJECTED. Violation of Architectural Invariant #A-14: 'No direct, synchronous messages emitted by the core execution path, to avoid latency at scale.' The proposal constitutes an unacceptable performance degradation.

5.3.2 Plan B

- The LLM proposed creating an endpoint on the `Executor` for another service to query.
- Recognitive finds no violations.
- Recognitive informs the LLM of the technical implications deterministically.
- Courtesy of contextual cost information available to the LLM via RAG, the LLM concludes this would significantly increase infrastructure costs and complexity.
- Rejected.

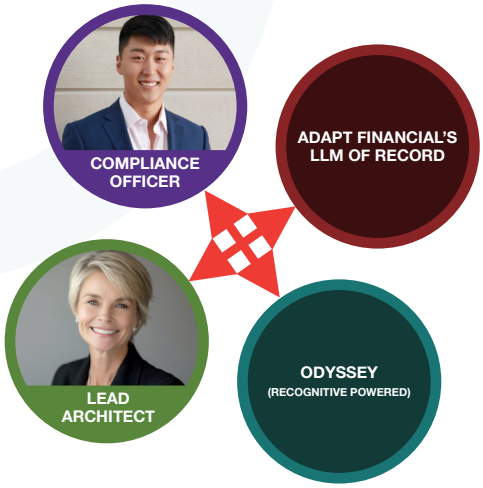
5.3.3 Plan C

- The LLM proposed modifying the data packet on the `ChronoBus` to include a high-precision `origination_timestamp` at the point of creation. And a lightweight, asynchronous `LatencyObserver` microservice subscribes to the `ChronoBus` feed and calculates finality latency without ever touching the critical execution path.
- ✓ OK. Continue.

5.3.4 Plan C is progressed for automated impact analysis

- Ephemeral Profiling: Recognitive spun up a sandboxed, in-memory clone of the `Executor` and `ChronoBus` modules with the proposed code changes applied.
- Telemetry-Driven Simulation: Leveraging existing telemetry, Recognitive ran a high-fidelity simulation, replaying data from the previous day's peak trading session to profile the performance of the modified code with zero human intervention.
- LLM-Generated Report: The structured simulation results — latency histograms, CPU / memory footprints, and security scan outputs — were passed to the LLM for synthesis into a human-readable impact report:

Predicted impact on core `Executor` latency: <0.1ms. New `LatencyObserver` resource footprint: minimal. Security posture: `LatencyObserver` has read-only access to a single data stream, minimizing attack surface. Required code changes: 14 lines in the `Executor` module; 75 lines for the new service.



The four parties 'in the room' in dialogue.

5.4 Action: from issue tracking to collaborative deployment

- Human Action: The lead architect and a compliance officer reviewed the report. The analysis was clear and auditable, and the risk quantified. They gave the 'proceed' command.

- Software Action: Recognitive initiated the changes immediately. It wrote the production-ready code, modified the `Executor` module, updated the system's test harnesses, and provisioned the necessary infrastructure in the staging environment via Infrastructure-as-Code scripts.

The team's role shifted from manual implementation to high-level supervision. They watched the automated pipeline execute, confident in the validated impact analysis. The process of deploying a secure and compliant solution to staging was reduced from a potential two-week sprint to under four hours.

5.5 Post-action assessment: from hope to certainty

- Staging: The new architecture ran in the staging environment under a 48-hour high-volume stress test.
- Continuous Monitoring: Recognitive observed the results of its own actions, comparing the live telemetry data against the predictions from its earlier simulation.
- Final Report: At the end of the test, it issued a final assessment:

  Post-action analysis complete. Observed latency on `Executor` peaked at 0.07ms, consistent with the <0.1ms simulation prediction. No new 'surprise' events were generated. The generative model has been updated to reflect the new, more accurate system state. The Odyssey platform is now verifiably in compliance with Directive 2095-08B.

5.6 To sum it up

What would normally have been a high-risk and time-sensitive regulatory change is transformed into a demonstration of market-leading agility.

All four parties — the technical lead, the non-technical lead, the AI, and the supersoftware — are ‘in the room’, allowing Adapt Financial to meet the deadline easily, avoid technical debt, and possess a fully auditable, machine-generated change record.

Recognitive makes the software itself a proactive, reasoning, and self-securing partner in its own evolution.

5.6.1 Outline of benefits

When a new task arises, there is often a realm of possible solutions. Rapid determination and implementation of the best way forward is a dramatic competitive edge.

Prior to LLM-assisted development, had a junior dev proposed Plan A, a senior dev would have rejected it from experience. But this is a slow feedback loop.

With LLMs, Plan A is proposed and it's considered a ‘good enough’ solution absent the expressivity of the software itself. A human would have to intervene, assess the risk, and decide whether to move forward or not.

With Recognitive, the supersoftware expresses why Plan A is a bad idea, and helps the LLM deduce the problem with Plan B. Recognitive pushes the human decision as late as possible, avoiding the ‘Pull Request Fatigue’ that plagues human-LLM collaboration today. It facilitates rapid testing and deployment of Plan C, securing compliance and leaving the system in a robust state with no technical debt.

6. Conclusion

Still to write:

- Recap of systemic significance.
- Call to action / next steps for adoption, collaboration, research.
- Future work on strategic implications.

7. Our foundations

7.1 Complexity theory

While there is no universally agreed rigorous definition of complexity, it is typically characterised as a system of many interacting components or agents, connected through a dynamic network of relationships. Such systems often exhibit nonlinear interactions, feedback, and history-dependence, giving rise to emergent and sometimes unexpected outcomes. In this context, causal relationships are difficult to isolate; causality is typically distributed, nonlinear, and context-dependent.

All living systems are complex and adaptive. Adaptive means the behaviours of participants in the system change according to the circumstances in which they find themselves.

It's useful to be able to distinguish complexity and complication. A car is complicated for example but not complex, i.e. it consists of very many different integrated parts but does not exhibit unexpected behaviour by design. Traffic on the other hand is not complicated but is complex, i.e. traffic is just a mass of vehicles and traffic jams can emerge for no obvious reason.

Many systems of interest entail both complication and complexity. For such a system to exhibit appropriate adaptability, for it to survive and thrive so to speak, it must exhibit a suitable sophistication to handle the dynamism of its environment. This requisite complexity[36] is perhaps best reflected in the following phrase capturing an idea first expressed by Einstein:

> Everything should be made as simple as possible, but not simpler.[37]

7.2 Bio-analogy and biomimetics

We take nature as our guide. As Aristotle figured out more than two millennia ago:

> If one way be better than another, that you may be sure is nature's way.

You could say nature, including all living processes by definition, has had substantially more time and capacity to try out different things to see what works and what doesn't. Nature is the ultimate R&D lab.

Biomimetics (aka biomimicry) is the purposeful emulation of nature's models, systems, and elements to solve complex human problems. Computer science has long drawn inspiration from natural systems and principles, although mostly via analogical reasoning than biomimicry. For example, while research into biomimetic

neural networks[38] explicitly seeks to replicate biological neuronal processes, today's mainstream neural networks (including LLMs) are better understood as analogies to biological systems rather than faithful emulations.

The line is blurred to the point that biomimetic design can be broadened to span inspiration, imitation, and integration[39]. Either way, the distinctions are instructive. In our contexts here, one may easily identify physical computing infrastructure as analogy (inspiration) and yet observe imitative qualities of the associated algorithmic behaviour, intended or otherwise.

At the risk of confusing matters, researchers observe for example that neural networks can emergently learn to perform analogical reasoning[40], a behavior that emulates a key aspect of human cognition. The design goal may then shift to fostering such emergent outcomes deliberately as best one can given system complexity.

Biological inspiration is abundant in our contexts here.

7.3 Cybernetics

Cybernetics is concerned with regulatory and purposive systems. Core concepts include feedback, variety, viability, and the role of the observer — specifically considering the observer a part of rather than separate from the system in question. It's been described as the science and art of understanding[41], and in terms of having a goal and taking action to achieve that goal[42].

It's applied in many disciplines including biology, ecology, technology, cognitive sciences, social sciences, and in designing, engineering, learning, managing, music, and conversation. Its application is potentially so broad it's been called antidisciplinary[43].

Cybernetics and AI have some similarities but:

> AI presumes that value lies in understanding "the world as it is" — which presumes that knowing the world is both possible and necessary. Cybernetics holds that it is only necessary and only possible to be coupled to the world sufficiently to achieve goals, that is, to gain feedback in order to correct actions to achieve a goal.[44]

Cybernetics provides the foundational framework for understanding governance as the steering and control of complex social systems through communication and feedback.

7.4 On governance

Governance is the determination of authority, decision-making, and accountability in the process of organizing anything[45].

Accountability is the obligation to take responsibility for one's actions, decisions, and their outcomes, including the duty to explain and justify them, and face consequences when unable to do so[46]. Accountability fosters ownership, transparency, and responsible behaviour, but we must ensure the agility with which superorganisation can adapt is not impaired in the process.

Any cybernetician will tell you that the purpose of a system is what it does[47], an idea often expressed as POSIWID. It's a provocation well suited to an age in which systems of consequence often exceed the comprehension of any individual or group. Its focus is operational, directing attention to effects rather than intentions, thereby enabling timely intervention whenever outcomes are deemed undesirable or just subpar.

For those familiar with the Cynefin framework[48], social systems play out in the framework's complicated, complex, and chaotic domains. POSIWID reminds us not to trust design intent alone in the complicated domain, but to verify through results. It's integral to operating in the complex domain in which cause and effect may only be clear in hindsight, and being action oriented, POSIWID is wholly supportive of organising in the chaotic domain.

POSIWID doesn't preclude holding system stewards accountable in broader moral or political terms, but it resists deferring action while such processes unfold. Responsibility is shifted from stated aims to observable results, supporting adaptive change even amid ambiguity or dispute. Of course, adaptive change requires control.

7.5 On control

Governance is most effective when it's embedded within the operational dynamics of the system itself rather than imposed externally.

By way of example, Watt's centrifugal regulator, the device spinning above the cylinder of a steam engine that controls the pressure to ensure it doesn't build up dangerously, is an integral and real-time part of the steam engine. It's considerably more effective in terms of responsiveness, stability, and reliability, and so overall system health, than an engine driver keeping an occasional eye on a pressure gauge and making intermittent manual pressure adjustments. It's direct rather than indirect, endogenous rather than exogenous.

In the lexicon of cybernetics, such a direct, endogenous mechanism implies that the system has an awareness of itself. Self-awareness enables a more complex and reflexive form of meaning-making[49].

7.6 Active inference

Active inference is a framework for understanding how living systems and artificial agents regulate themselves by continuously predicting and minimizing the mismatch between expected and actual sensory input; minimising the surprise!

It inherits the idea of self-regulating systems operating through feedback loops and homeostatic control from cybernetics. It formalizes these loops as probabilistic inference in a generative AI model, where perception updates beliefs and action changes the world to reduce prediction error.

7.7 Semiotics and umwelt

Semiotics is the study of signs and meaning-making. A sign is anything which 'stands for' (represents) something else and it can take any form.

> Anything has the potential to be interpretable, but nothing has an intrinsic meaning; for human beings, something becomes a sign when it is interpreted as signifying something.[50]

The role of interpreter corresponds to the cybernetic regard for the observer.

The field has two primary traditions, the philosophical (closely related to logic) and the linguistic. Both are applicable in our contexts. It's considered to have three branches: semantics (the meanings of signs), syntactics (the relations between signs), and pragmatics (the use of signs). Again, all are applicable here.

In the philosophical tradition, the understanding or mental concept that a sign creates (known as the interpretant) is itself another sign or signs. In the linguistic tradition, a sign may be said to stand for one thing if only because it doesn't stand for other things. Either way then, semiotics can be thought of as signs in relation to signs.

Computer science conceives of information as something that may be transmitted from A to B. In the context of living systems however, and in accordance with semiotics, we appreciate that an organism isn't the recipient of information transmitted to it but rather a system participant that infers perturbations as being informative; as being a sign.

> The environment contains no information. The environment is as it is.[51]

In other words, information requires an observer. Each observer has an *umwelt*, a subjective experience of the world based on its cognitive capabilities[52]. If any of this paper's authors overhear a conversation in Mandarin for example, our world is unchanged for none of us comprehend the language. We cannot interpret any signs to find meaning. Even if English is spoken, our world will be little affected if we lack the context to understand what is being said.

> Without context, words and actions have no meaning at all.[53]

The construction of meaning is a social imperative. Social systems don't think or feel as one, but they reproduce themselves through communication processes that construct meaning[54]. A meaningful coherence amongst participants is achieved as the words are put into action and the participants appreciate the effects[55].

We can then conceive of AI systems as new semiotic actors in human cultural ecologies.

7.8 Biosemiotics

Semiotics asks 'How do animals including humans use signs?' In contrast, biosemiotics presents semiosis as a precondition for life not a product of it.

Biosemiotics interprets biological processes, such as cell signaling, animal communication, and genetic expression, as fundamentally sign-based phenomena. Where there is life, there is communication and interpretation.

While it isn't considered mainstream biology in the Kuhnian sense that it isn't incorporated into the dominant paradigm, it engages directly with biological systems (e.g. cells, genes, ecosystems) and aims to understand how living systems function.

The methodological gap between biosemiotics and conventional biology is narrowing. Biologists increasingly recognise semiotic concepts as useful descriptive tools and adopt biosemiotic models as heuristics for understanding biological phenomena such as signaling, regulation, context-sensitivity, and adaptation.

Complexity theory in particular offers a bridge to semiotics, a dynamical substrate, especially in theoretical biology, systems biology, and bioinformatics. It explains how structures and processes arise at all levels — genetic, cellular, organismic — that can function as signs. Self-organising systems emerge that are capable of treating certain patterns not just as causes but as signs; information about something else that guides the system's future state.

7.9 Autopoiesis and organisational closure

What distinguishes the living from the non-living?[56] In each case, a system is living when it's defined by a boundary within which are the systems it needs to regulate and maintain itself; autopoiesis. It includes the idea of organisational closure which means that a system can be viewed as a network that works to maintain itself. In plain language, it forms a whole.

7.10 Cybersemiotics

Cybersemiotics integrates a number of disciplines including cybernetics, biology, semiotics and biosemiotics, autopoiesis, and embodied cognition.

Cybersemiotics draws conceptual analogies from biology and biosemiotics, and we channel it here for heuristic understanding and replication in complex contexts; not as ends in themselves but as means to meanings, as meanings to our end.

7.11 Genetics

An organism's genotype (its genetic constitution) functions primarily as information storage and does not itself contain the machinery to express or process that information. An organism's cellular machinery are expert late binders so to speak, i.e. they 'interpret' genotypic information in the moment, in context, and act on it.

The separation of encoding (DNA) and expertise (proteins) underpins how life systematises encoding and expression through specialised building blocks highly suited for those roles — nucleobases and amino acids respectively. While the DNA provides the instructions, the expression of those instructions can vary due to multiple biological mechanisms in different contexts. The separation affords complexity and evolvability, and with extremely rare exceptions all known cellular life works like this. Ditto supersoftware.

7.12 Artificial (general) intelligence

An influential paper[57] explores two divergent visions of intelligence and so divergent visions of artificial intelligence. One, widely cited in the field, emphasises task-specific performance:

> [AI is] the science of making machines capable of performing tasks that would require intelligence if done by [humans].[58]

The other highlights generality and adaptation:

> AI is the science and engineering of making machines do tasks they have never seen and have not been prepared for beforehand.[59]

This distinction frames current debates. Large language models can generate novel outputs by recombining patterns from training, but they do not exhibit robust generalisation to out-of-distribution tasks. With LLM performance effectively defining AI today, the more demanding criteria are now associated with the prospect of artificial general intelligence (AGI), for example:

> [AGI] demands a fundamental shift towards systems capable of genuine fluid intelligence, the ability to adapt to novel challenges and solve problems efficiently, much like humans do.[60]

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