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Ainolabs Cognitive Fitness: Sidebar Enterprise World Models

From Automotive to Enterprise World Models

We discussed autonomous systems and self-driving vehicles earlier to grasp the essential components and features or a world model for an enterprise. We assumed that a (manufacturing) enterprise is a close analogue to an autonomous system with sensors, noisy inputs, physical constraints, long feedback loops, and real cost of error.

As earlier, a World Model is a system and mechanism to manage ambiguity. ERP, dashboards etc are different, and while often valuable and relevant to a company's operations, not the direct focus of this discussion. ERP is a key data source, though.

What Is the "World" in a Manufacturing Enterprise?

An enterprise's world is not limited to the factory. It is a set of interacting, partially observable state variables that reflect relevant and essential attributes of the operating environment. These include:

- Demand (current and future)
- Supply (materials, labour, energy)
- Capacity (machines, shifts, uptime)
- Quality (defect rates, yield)
- Cash (working capital, credit)
- Risk (supplier reliability, regulation, weather)

Each variable can and is perceived differently by different stakeholders within the enterprise over time. The farther into future the more diversity and wider spreads should be expected. For example, Demand might be takes as "firm orders" by production, or "viable leads" by sales. Neither is wrong, and both should be considered when making decisions.

Metrics, measurements – Sensors in the Enterprise

Manufacturing enterprises already have sensors. There are Quality Control inspections, operator reports, continuous machine and other logs, Inventory systems, machine telemetry, supply chain tracking tools, CRM and customer and market demand estimates as examples.

Some of these could be taken as literally as the sensors of a vehicle – "speed" is a clear, directly measurable variable for a car, and so are the metrics of "machine telemetry". Several of these "sensors" are somewhat subjective, though, and should be treated as time and probability-based estimates. They are partial, biased, often delayed, and could be politically influenced by the motives and preferences of the people that generate and deliver them.

Accordingly, most reports should be treated as hypotheses instead of facts. This is inherent in an organization, so we are designing for this, for handling uncertainty and apparently conflicting inputs for an automated system.

What is the purpose of an Enterprise World Model?

The enterprise world model exists to answer:

"What states of the business are plausible right now, and which decisions are robust across those states?"

State of business is an open-ended phrase. It includes future scenarios, since current state could direct to increasing sales efforts and possible results, changes and improvements in sourcing or similar possibilities in all aspects of the company's current and future operations.

World model should not be expected nor built to provide single numbers, or to create systems of record, or not to enforce consistency. The opposite holds: The World Model should make ambiguity and different expectations explicit and visible.

For example, inventory is a distribution instead of a scalar, and time-bound distribution at that. The inputs could be 10 000 units in ERP, 9200 in warehouse scans, production giving a verbal message "we are short" and finance reverting to their role an indicating that "Books are correct".

The World Model should retain these input reports as they are and generate a distribution of expectations.

Communication patterns between the Enterprise World Model and other system parts

In this context, system components submit evidence. Conclusions and actions are a separate, explicit step, possibly including human intervention.

Interfaces should be indicating relevant and appropriate level of detail for evidence and avoid premature conclusions. Hence the data should be e.g `{ OperationalEvidence: source; observed_signal; confidence; timestamp; bias_profile}` rather a simple status, which implicitly and explicitly includes the full semantic and epistemic conclusion: `{ MachineStatus: state = "OK" }.`

The World Model maintains internal belief distributions about demand, capacity, supplier chain, cash flow etc. That is why "sensors" (data and observations) need to be provided as evidence instead of conclusions.

Evidence and beliefs are tracked as correlations. For example, supply chain delays and overtime may be correlated product (delivery) quality and defect rates. Further these may relate to beliefs store in the systems.
It is important for the World Model to preserve disagreement between sources. This allows the people in the enterprise learn faster.

Decision-Making: Acting Without Full Resolution

An enterprise needs to act profitably.
Most enterprise prefer growth to stagnation.

Certainty is of lesser importance. Enterprises need effective decisions. Absolute certainty[1] is not necessary. Waiting for it could be counter-productively.

Instead of certainty, reasonable and sufficient preparation for possible future scenarios is useful. Some risks and opportunities are asymmetric. The impact of e.g. supply chain problem for product deliveries and revenue may be tolerable, or catastrophic. In the latter case the cost of additional surplus materials inventory would be a sensible hedge position.

Profitable growth is an obvious desire for any enterprise. This is achieved, in Ainolabs' opinion, by supporting **robust actions under uncertainty**.

Robust actions under uncertainty

Robust action is used as a term in Decision Theory, specifically in theory called "Robust Decision Making". For this discussion, we'll refer to Belief-Informed Robust Decision Making (see https://www.sciencedirect.com/science/article/pii/S1364815222002602).

A robust action is different from an optimized action. An optimized action may be best if all assumptions are correct, i.e. perfect foresight is available.
In contrast, a robust action performs reasonably well across many scenarios. It may be worse than the optimal choice, but on the other hand it avoids large downside risks.

Properties of a Robust action include properties such as

- Works under many plausible futures so that success does not depend on one specific forecast being correct.
- Low downside risk. If assumptions prove wrong, losses remain limited to manageable and tolerable levels. One does not "bet the farm" by coincidence.
- Graceful degradation. Performance deteriorates slowly rather than catastrophically when conditions change.
- Preserves optionality. It keeps future choices open instead of locking the decision-maker into a narrow path.
- Tolerates model error. Even if estimates, predictions, or data are somewhat wrong, the action remains useful.

Enterprise automation and the application of Machine Learning, or other AI or Smart technologies all need to generate robust actions to be productive tools for a company.

Uncertainty versus Single Source of Truth

Single source of Truth is an enterprise architecture principle. It is also very attractive to humans otherwise, but we'll stay within enterprise systems.

The essence of Single Source of Truth (SSoT) is an information design principle ensuring that every data element is mastered, edited, and stored in exactly one authoritative location.

[1] There are life and mission critical systems, as well as regulatory aspects that require certainty, in some cases absolute certainty. Those are out of the direct scope of this discussion, although such constraints can be expressed in similar terms as other beliefs.

SSoT is applicable for Systems of Record, i.e. data that indeed is irrefutable, e.g. accounting, or current warehouse inventory in the ERP system.

Single Source of Truth is an operational data-management architecture to enforce consistency by eliminating data variability.
Robust Decision Making and beliefs apply to variability and uncertainty during decision-making. Decisions and automation work well if operational data is clear and SSoT in the Systems of Record can be maintained.

This is not the case for AI or Machine Learning (ML) – "Smart" – systems, which is the why there needs to be a World Model, or collection of time-bound probabilistic beliefs as an Enterprise World Model to support decisions and automated decisions in ambiguous, unclear, uncertain, situations, especially when there can be differences between the beliefs and expectations held by different stakeholders.

Robust Actions are essential for an enterprise, and explicit Belief Management as a World Model is necessary to automate Enterprise Workflows.

A somewhat similar difference should be made for ML models. As a litmus test, the question "Would we allow a junior analyst to assert this as fact?" could be used.
If the answer is no, then AI-ML should not be allowed to make the decision.

Company Culture, Values and Strategy in a World Model

The World Model reflects enterprise strategy, culture and values. It is not a direct representation nor archive, support system or similar to them. Instead, the World Model reflects the reality set by the enterprise's actual characteristics indirectly in priorities, probabilities, constraints and asymmetries between the temporal and probabilistic beliefs stored and maintained in the World Model.

Strategy is viewed here as constraint rather than a set collection of targets. Strategy can be expressed as a set of tolerable errors: "which errors we are willing to tolerate". Strategies often describe the end state of a time period – "what we want" – which is very valuable and useful for a company's people to understand and share. That goal is less effective as an operational tool for automation – or effective and efficient execution of workflows, possibly with the help of automation.

If such a World Model is created and maintained, the enterprise has an honest and explicit collection of its beliefs and expectations at any given time. The people in the company are essential to maintain that collection, preferably in a system designed for managing beliefs. In that case, Machine Learning can be useful and productive in assisting or directly managing and controlling suitable workflows.

A world model is, descriptive, probabilistic, time-bound and explicit.
On the other hand, if the world model is a collection of beliefs held by the people in the enterprise it should have clear similarities to company culture, values and strategy. These similarities are indirect.

This indirect representation of the company is outside the strict scope of workflow automation, so we won't dive into that. However, we do note that there is a preferably strong connection between those and the material in the World Model, as held in a Belief Management System. As long as that is the case, automated workflows will operate sufficiently close to the purpose and intent of the company, making **Robust Actions**.