Relevance of MDE in an increasingly dynamic world

Perspective of an industrial researcher

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Not too long ago

Experience & expertise driven

Largely manual

Small quantum and low rate of change

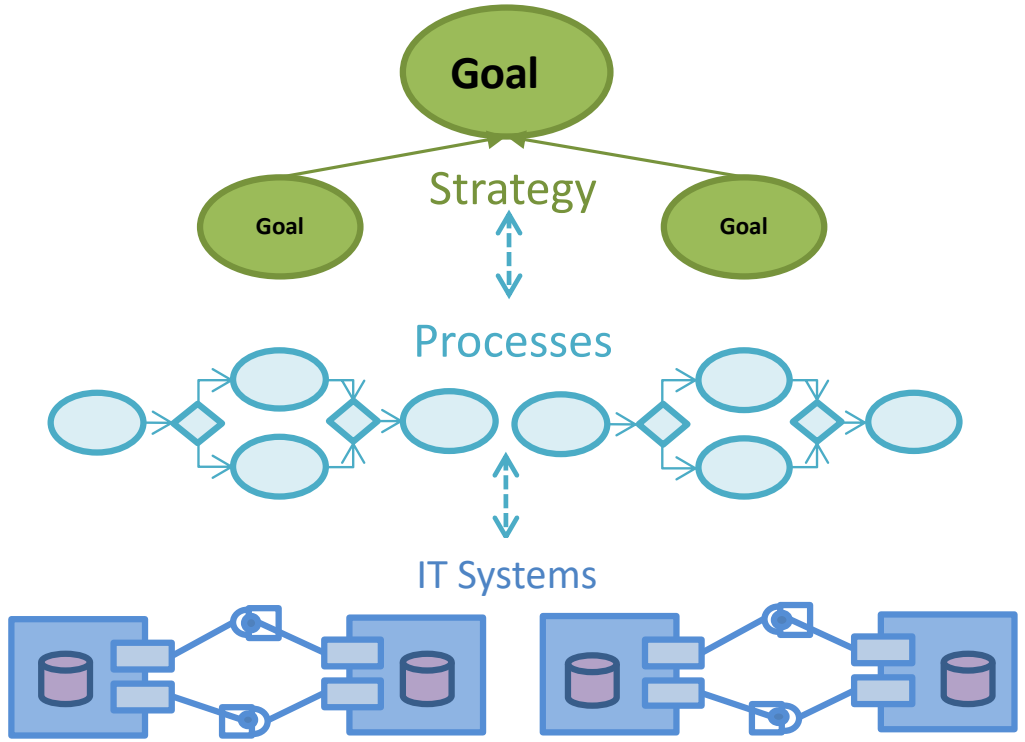
Large window for recovering investment

Manual change management the norm

Delivery certainty the primary objective

Change the business

Run the business



Decision -making

Demand

Fresh development, Evolution, Migration, Systems integration, Process reengineering…

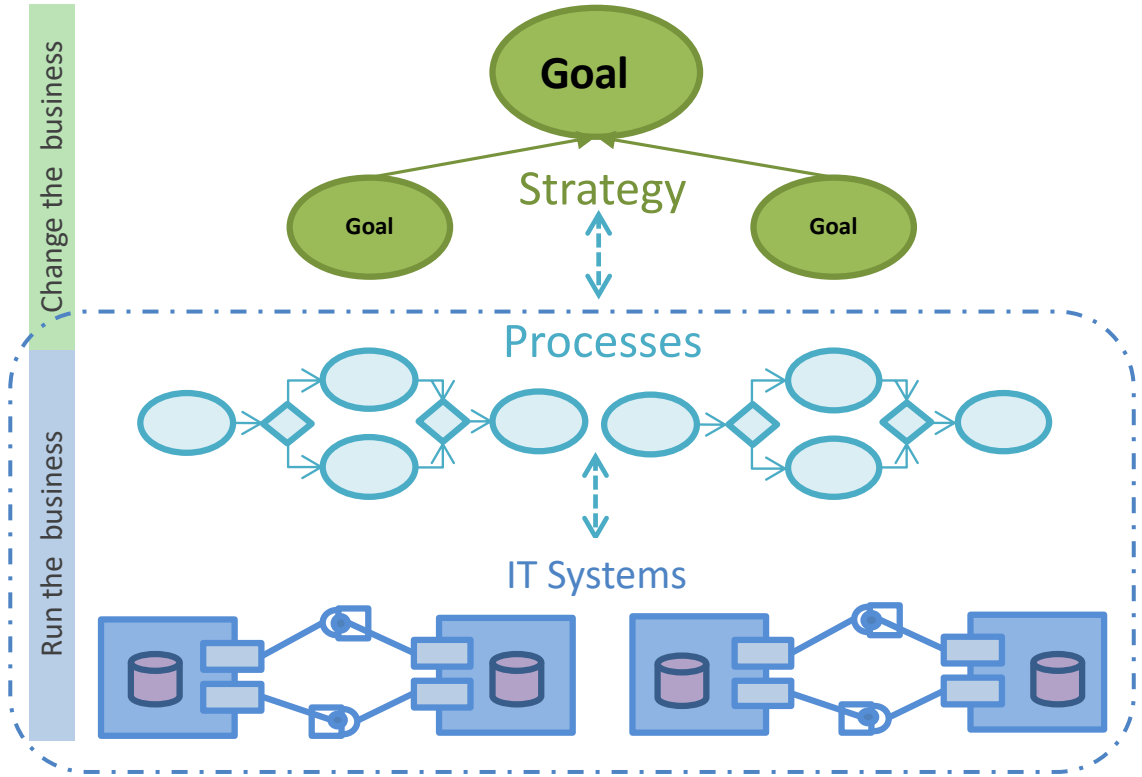
Focus of MDE

Automation the primary focus

Shift from coding to modelling

Early detection of errors, Automated code generation & testing, Precise change management

Principled approach, Repository centricity, Effective coordination in large teams



Focus on code generation and testing of software systems

Significant entry barrier – DSLs do address this issue but …

Poor exposure to workforce / students

Less attention to modelling of system of systems and/or stakeholders

Times they're a-changin

High change dynamics

Human-in-loop automated decision-making is the need

Data-driven and justification-backed

Change the business

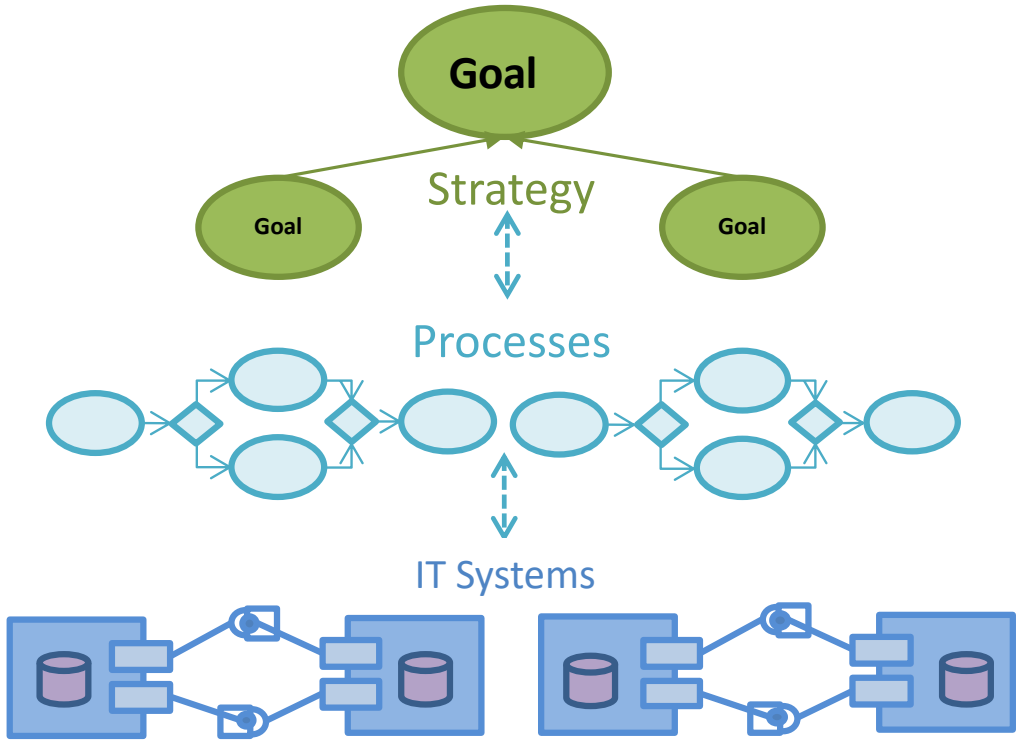
Run the business

Large quantum and high rate of change

Shortening window opportunity

Manual change management ineffective

Continuous adaptation is the need

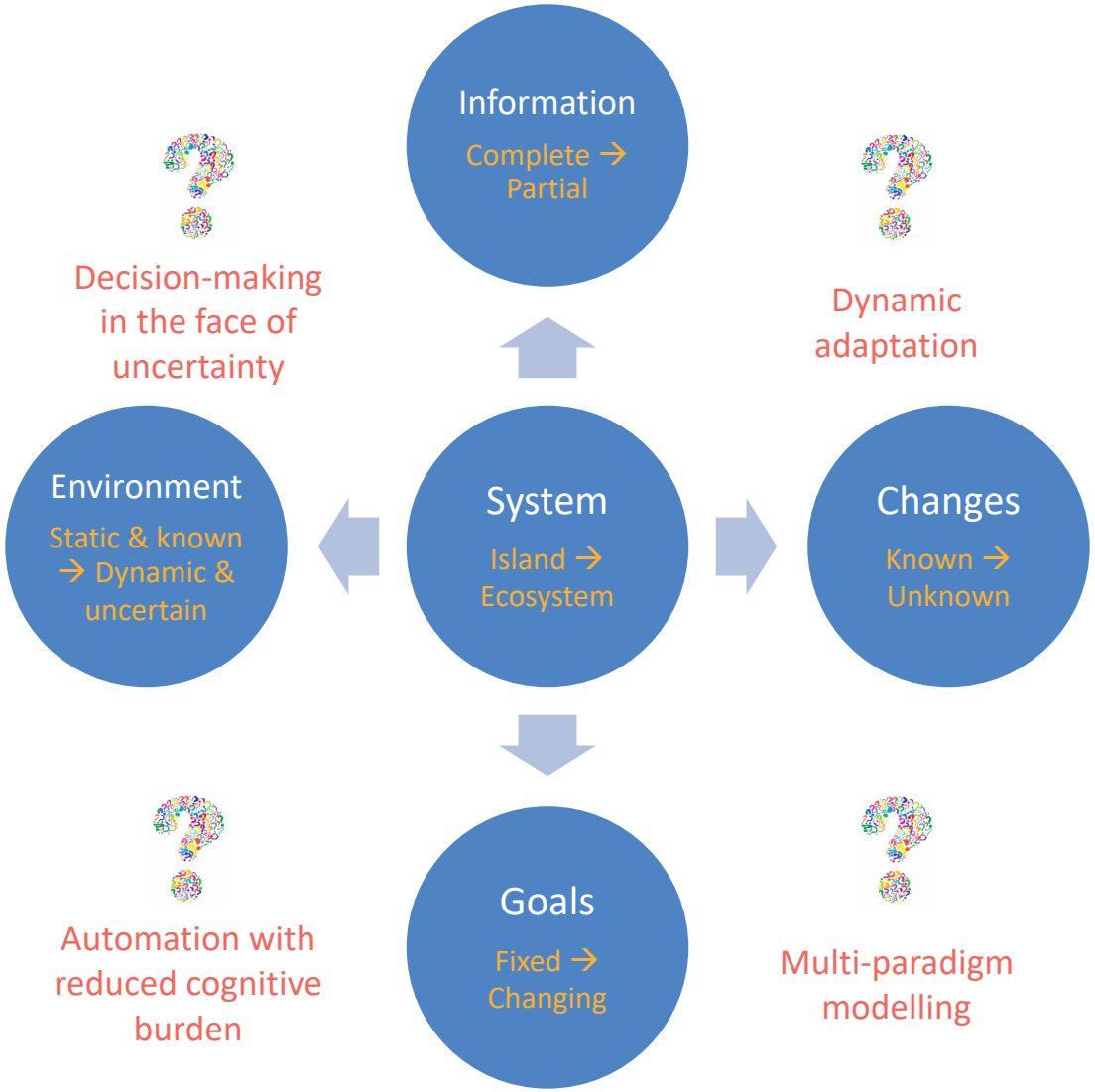


Decision-making

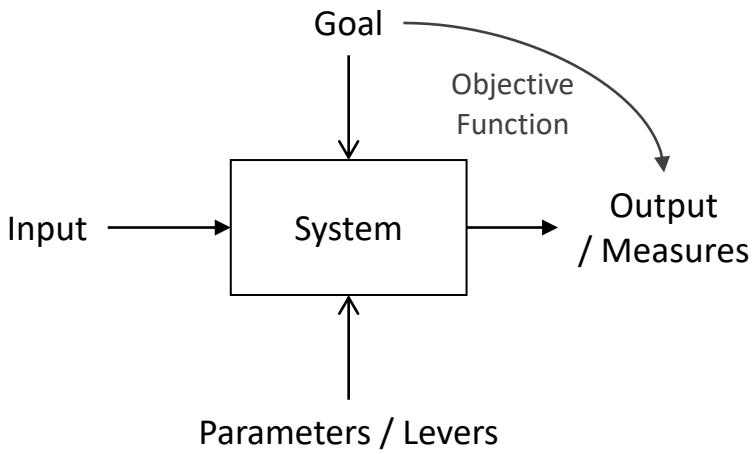
Demand

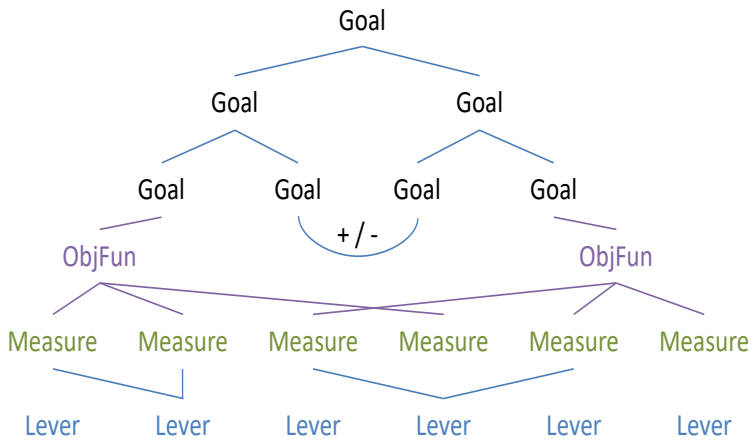
Fresh development, Evolution, Migration, Systems integration, Process reengineering…

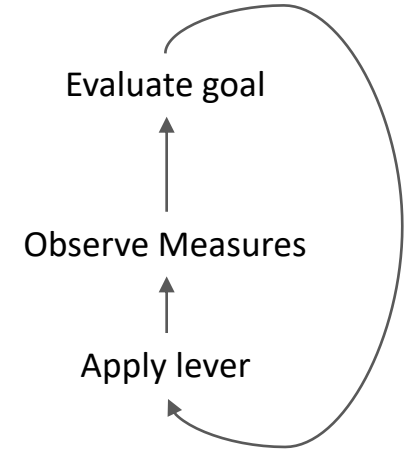
New needs emerging



Decision-making in the face of uncertainty







MDE focusing on code generation and testing of software systems
Significant entry barrier: DSLs do address this issue but…, Poor exposure to workforce / students
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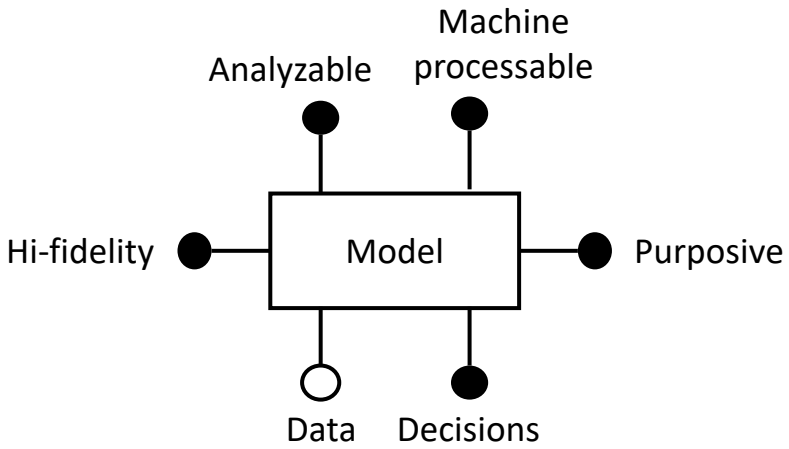
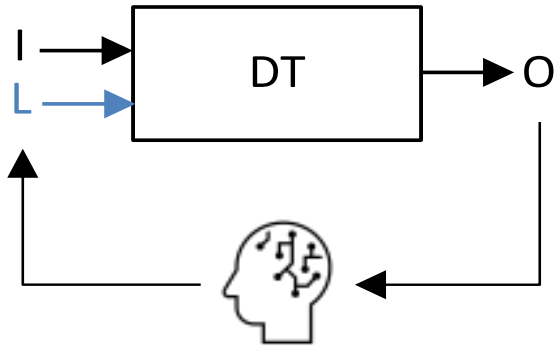


Mathematical

Learnt from past data



Decision space exploration

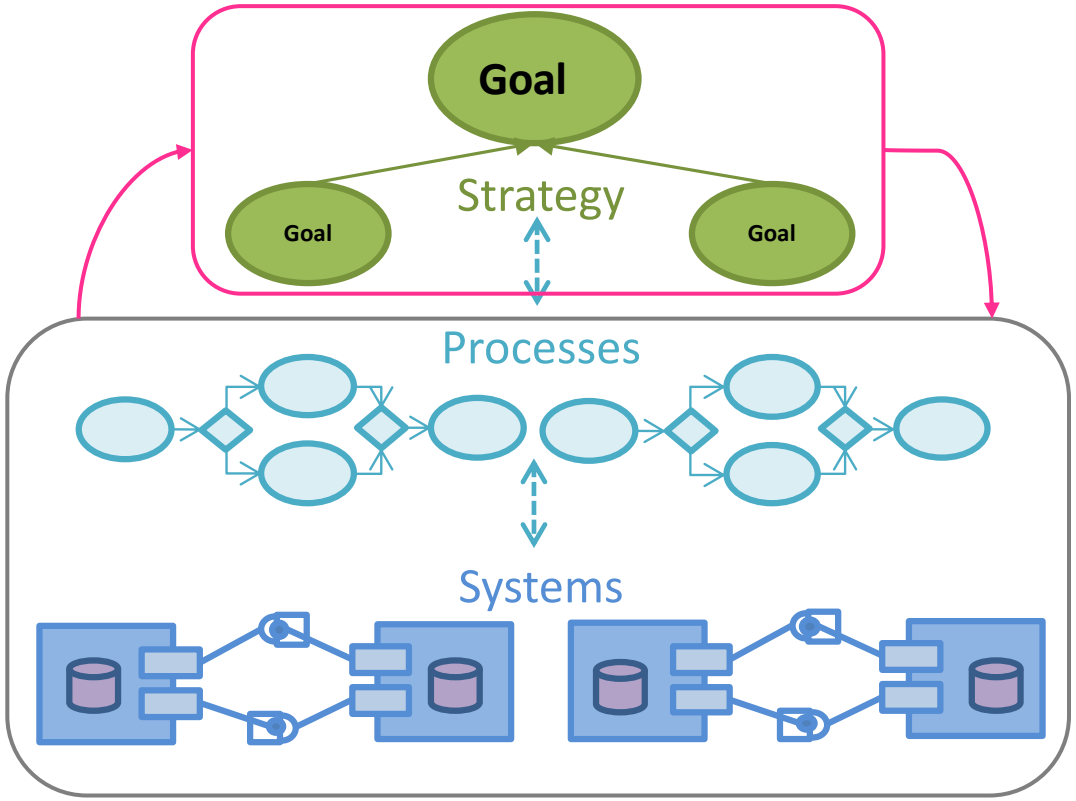
Adaptation

Customer needs, Technology advance / obsolescence, Competition actions, Regulatory regime, Geo-political events...

Change management

Change identification
Impact computation
Change effectation
Optimal testing

MDE helps



Software Product Lines

A priori knowledge
What can change
Where and ***How***

MDE provides
tech independence

Cast-in-concrete implementation based to point-in-time static knowledge

MDE focusing on code generation and testing of software systems
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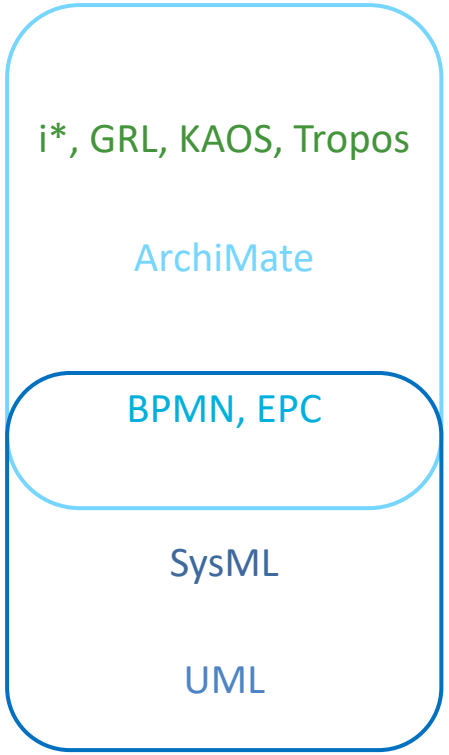
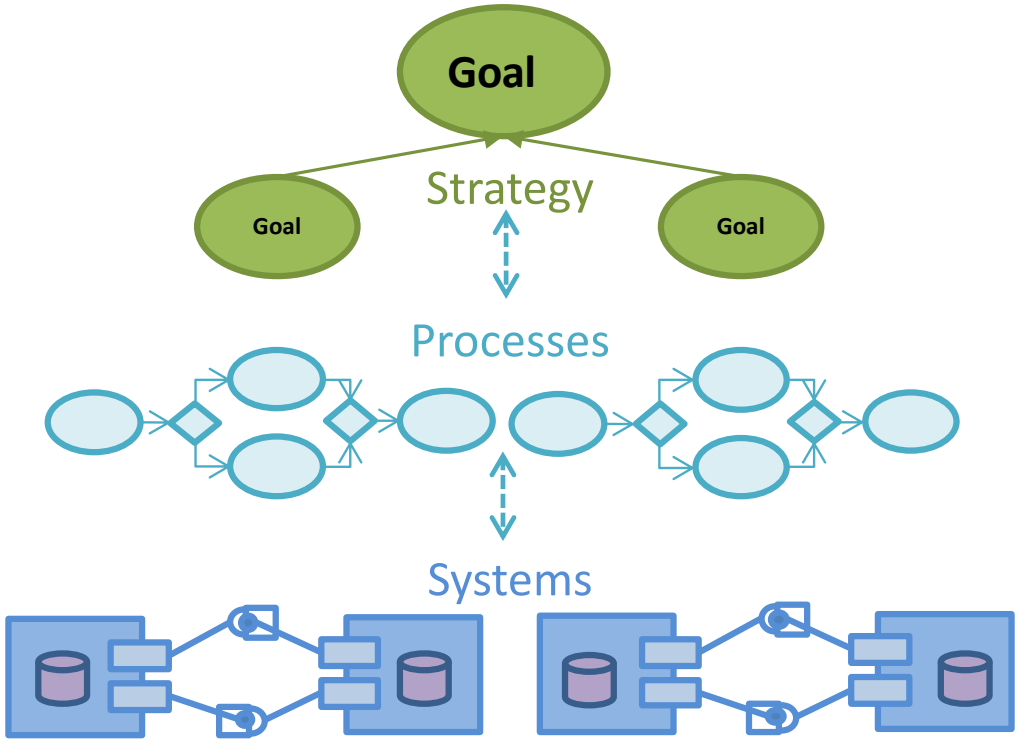
Multi-paradigm modelling





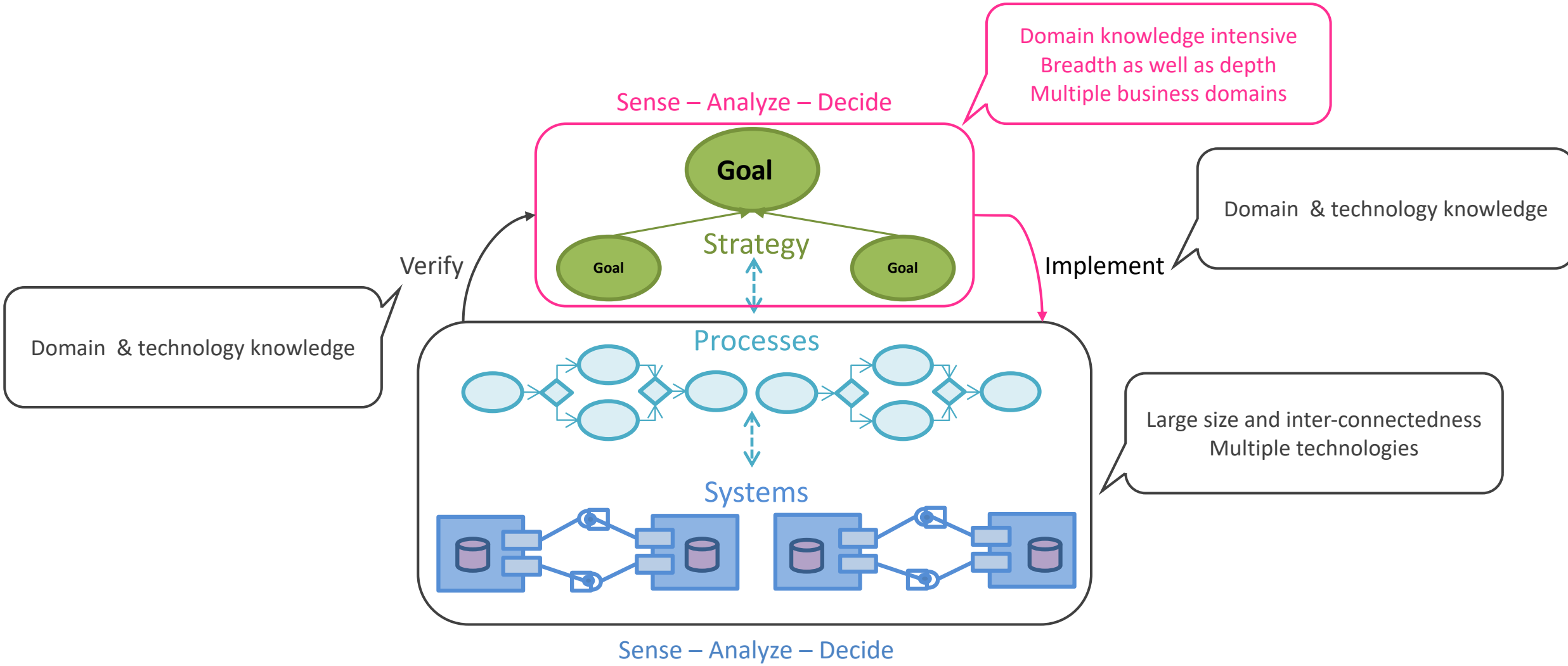
Designed to model a specific aspect using best-for-purpose formalism

Not intended for working together with other languages

Tool dependencies introduce another barrier

Poor / no support for deep neural nets

Automation with reduced cognitive burden



MDE relying on modellers to possess the required knowledge
DSLs aim to reduce domain-technology barrier but…, Poor exposure to workforce / students

A line of attack

Digital twin as a decision-making aid

Learning-aided adaptation

Decision-making in the face of uncertainty

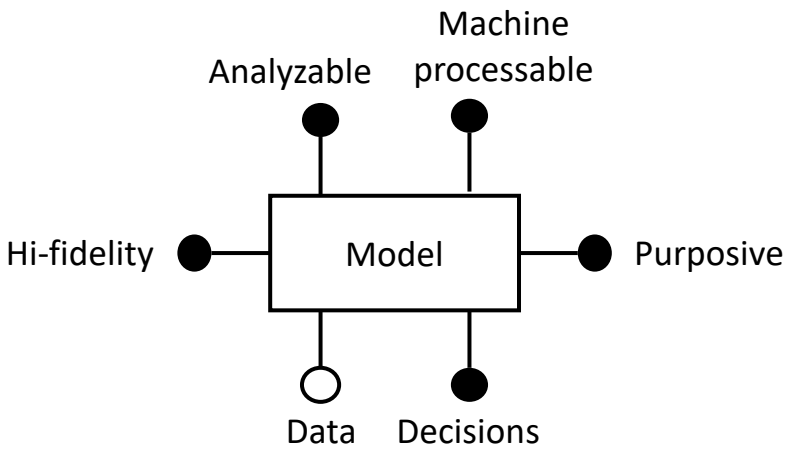
Dynamic adaptation

Automation with reduced cognitive burden

Multi-paradigm modelling

Leveraging Gen AI for addressing industry-scale problems

Digital twin as a decision-making aid



Specification & execution language
Validation & transformation machinery
Domain-specific semantics & constraints
Purposive meta model as a lens

Simulation-based decision-making

System as a set of Actors exchanging messages

Actor

State = a set of *attributes*

Behaviour

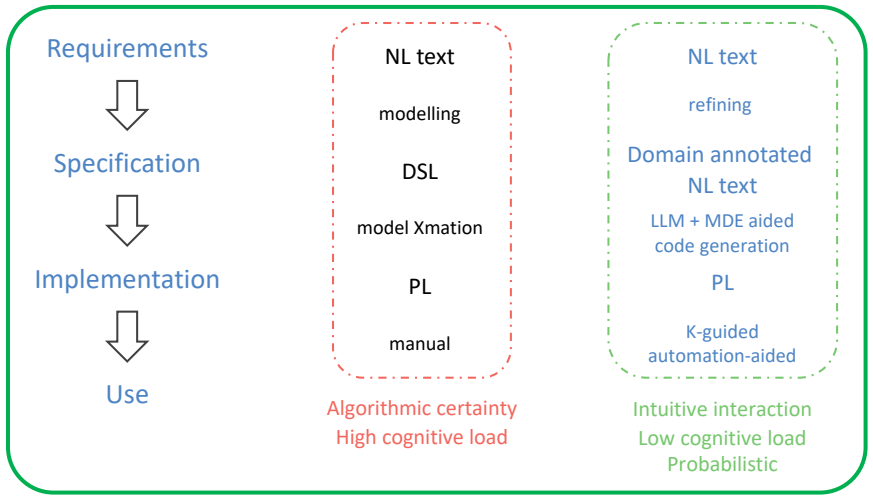
On *event* && *condition* do $action_1@p_1$, $action_2@p_2$…$action_k@p_k$

Action = change *state* | send *message* to *actor* | new actor | become actor

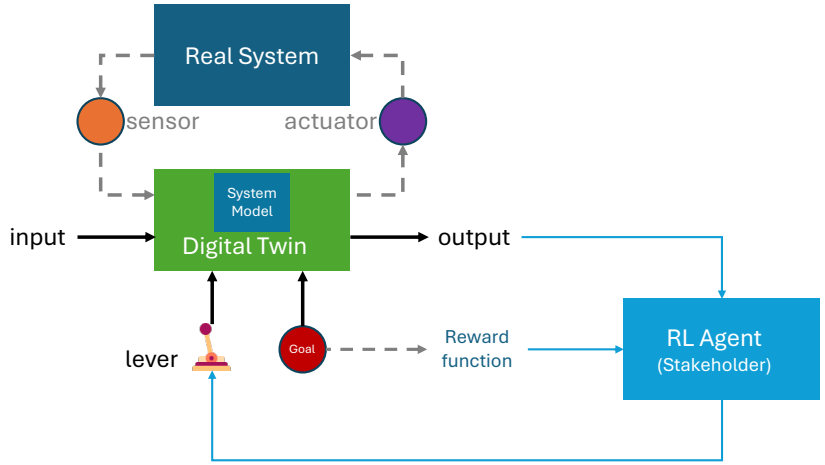
Message = < *event*, *relevant data* >

System behaviour emerges from Actor interactions

MDE assisted implementation of digital twins



Algorithmic & Gen AI techniques



Decision space exploration with reduced cognitive burden and latency

Leveraging Gen AI for addressing industry-scale problems

Large size and complexity

Shortening window of opportunity

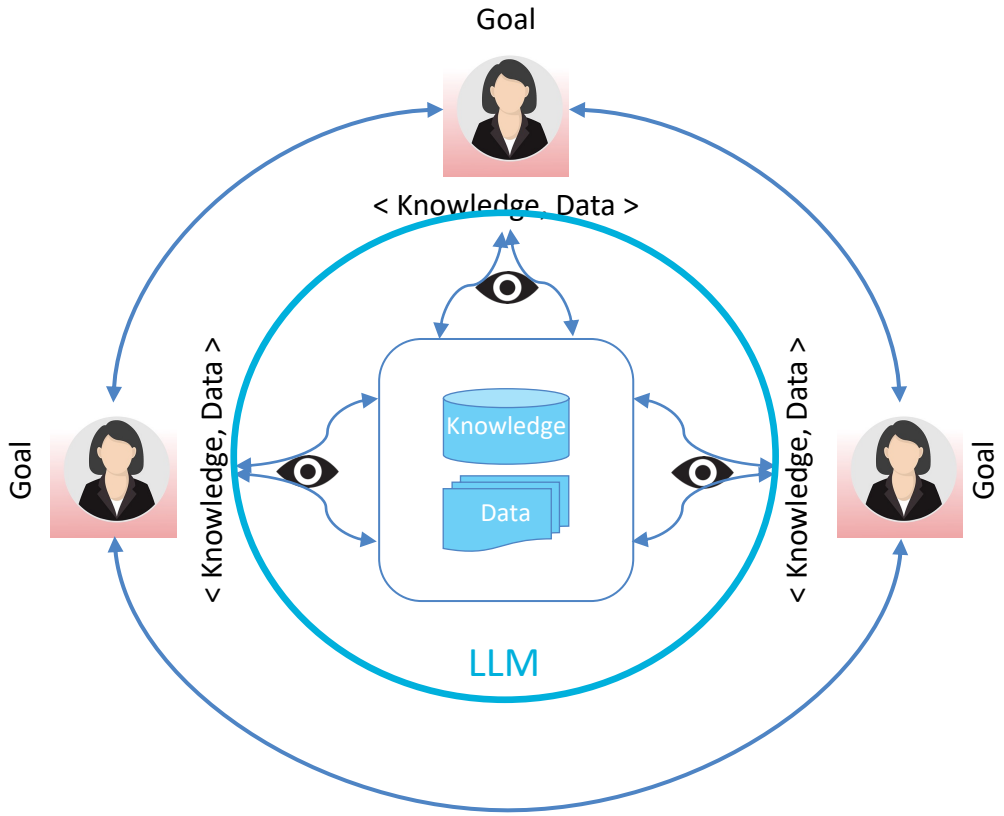
Diverse expertise

Goal-guided coordination

Requires external knowledge & data

Large cycle time ∴ Persistent memory

Large cognitive burden



Knowledge about domain, problem and solution available in public domain

Mechanisms to bring local data, information and knowledge

Big abstraction gap between problem domain and solution infrastructure available

Significant cognitive burden

No out-of-box support for multi-session coordinated use by a team

Universal Machine : Special Purpose Machines :: LLM : Domain-specific contextualized task-specialized LLM

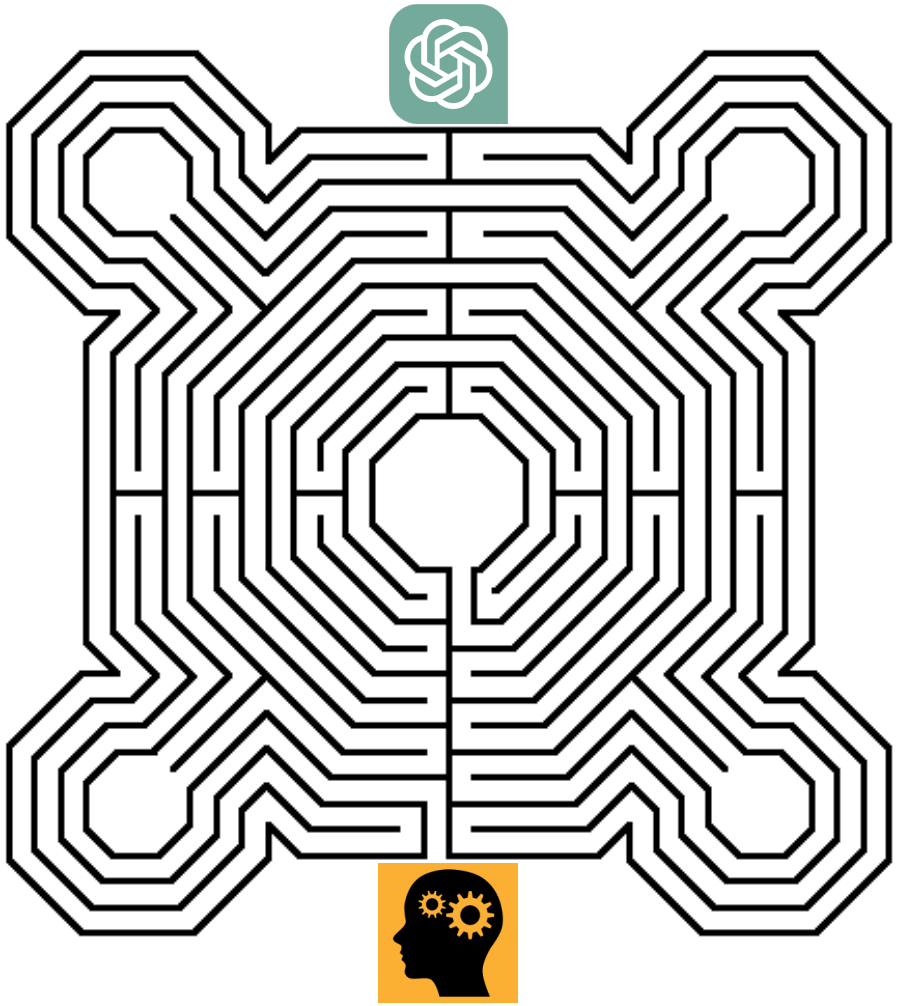
Question answering for problem solving

Local context missing; Validation of response; Hallucination; Bias

Domain

Information

Which questions to ask?
What context to provide?
What's the right order?
How to maintain context?
When to backtrack?
How to stay relevant?



Is the answer correct?
Is the answer complete?
Is the answer consistent?
Is the answer relevant?
What to carry forward?

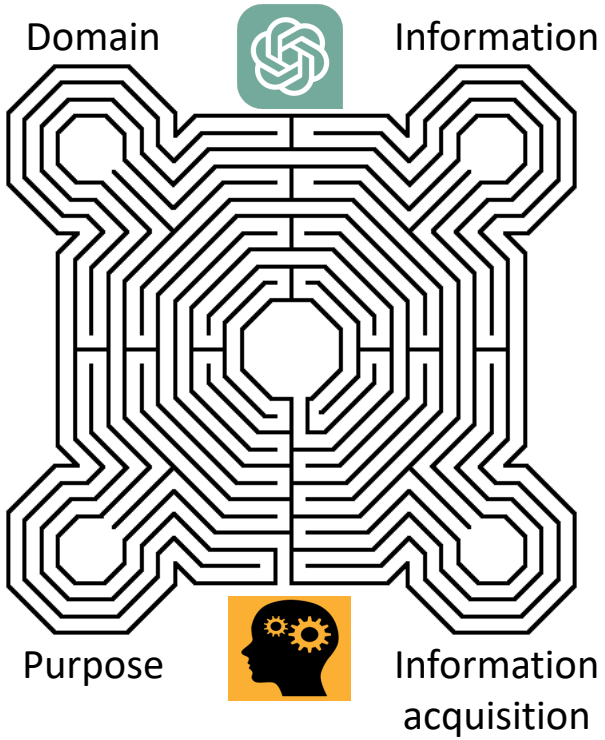
Purpose

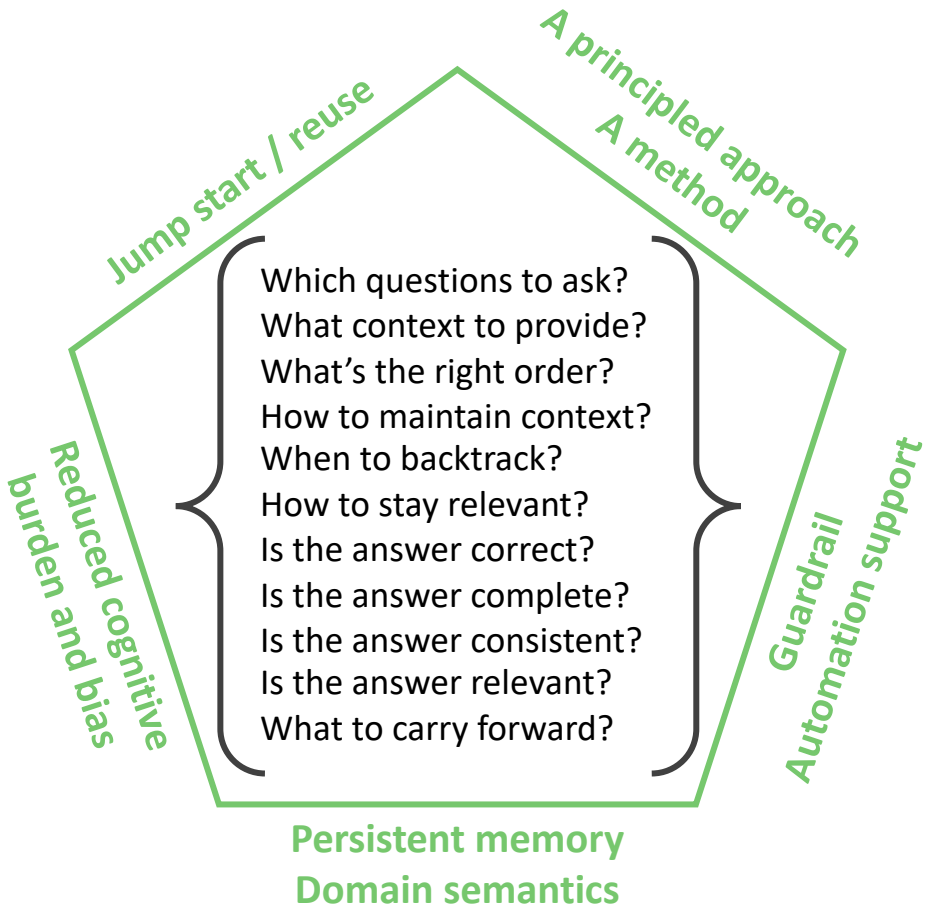
Information acquisition

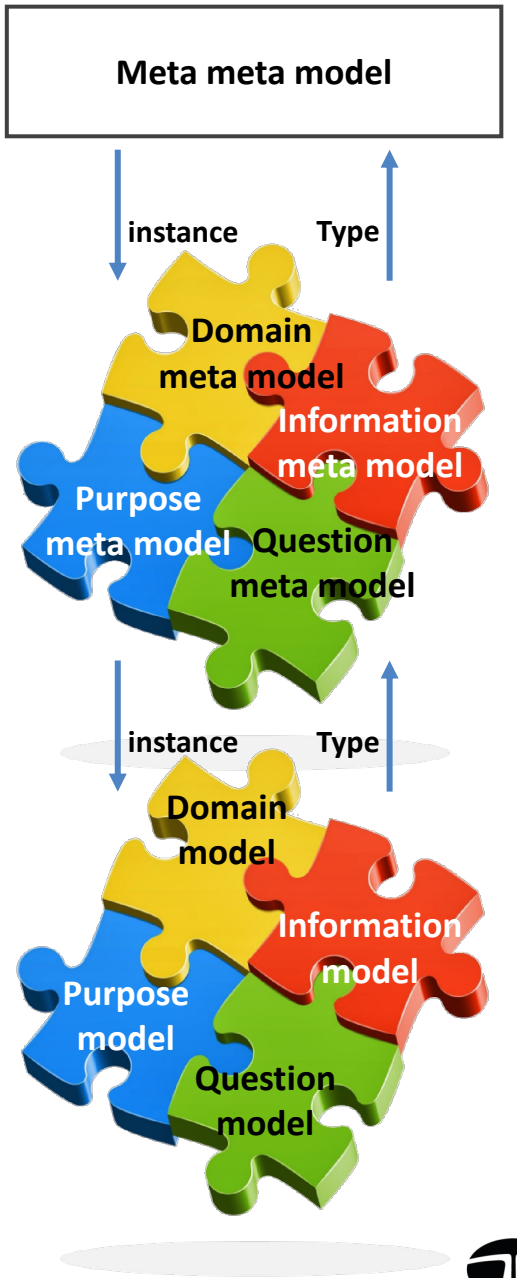
High cognitive burden; Variant quality; Bias

Repeat from scratch for every problem

Where MDE can help?





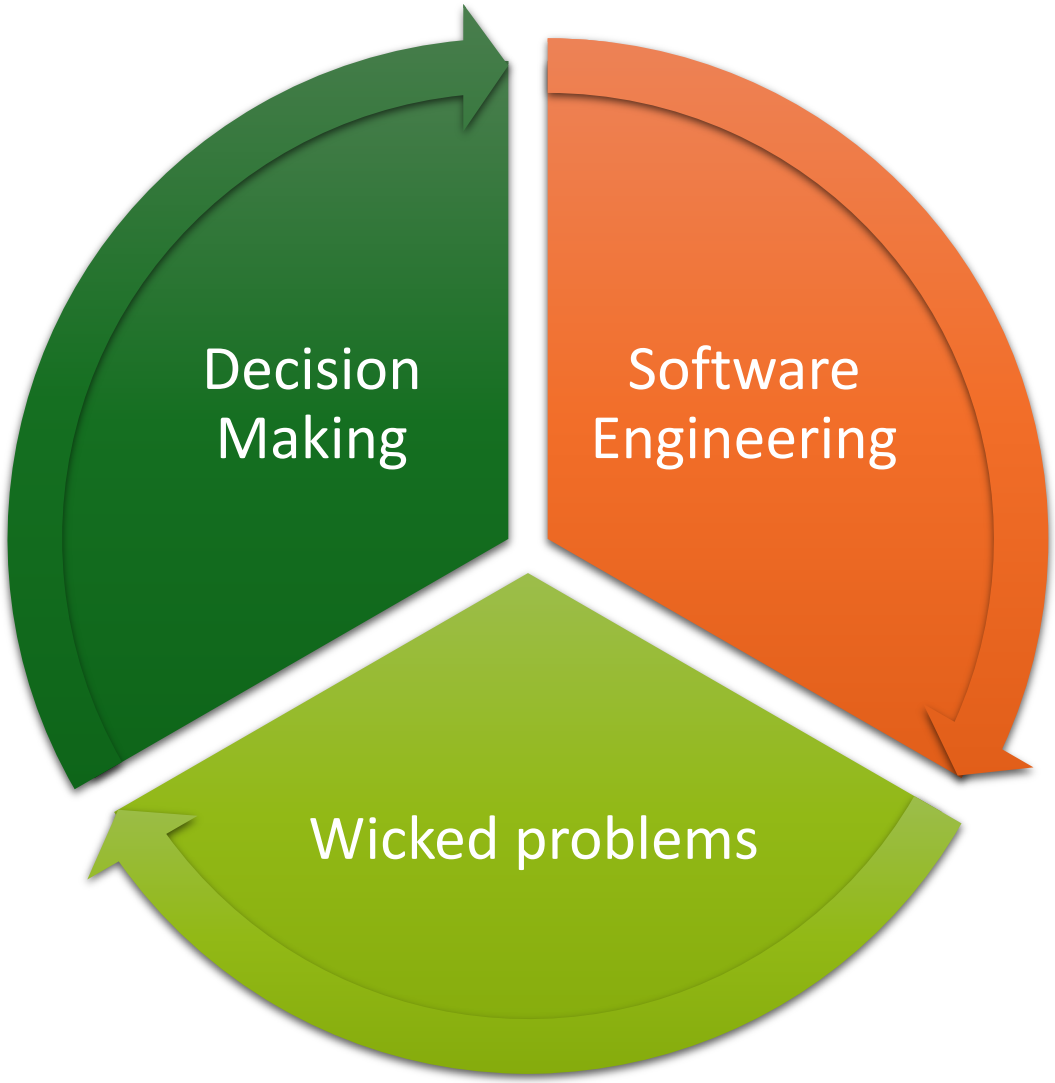


Real world illustrators

Decision-making in Telco

Shop stock replenishment in a retail chain

Supply network optimization for a logistics major



Digital Twin Life Cycle

Software development life cycle

Software modernization

Pandemic management

Man-tiger conflict

Water management

Symbiotic integration of LLMs and MDE is the key value-add

Open challenges

Validation & verification

Real time response at scale

Early warning system

High cognitive burden

Decision-making in the face of uncertainty

Automation with reduced cognitive burden

Dynamic adaptation

Multi-paradigm modelling

A-priori assurance

Real time response at scale

Current limitations of LLMs

Usability of LLM + MDE integration

Interoperability

Analysis support

Usability & Scalability

Standards

In summary

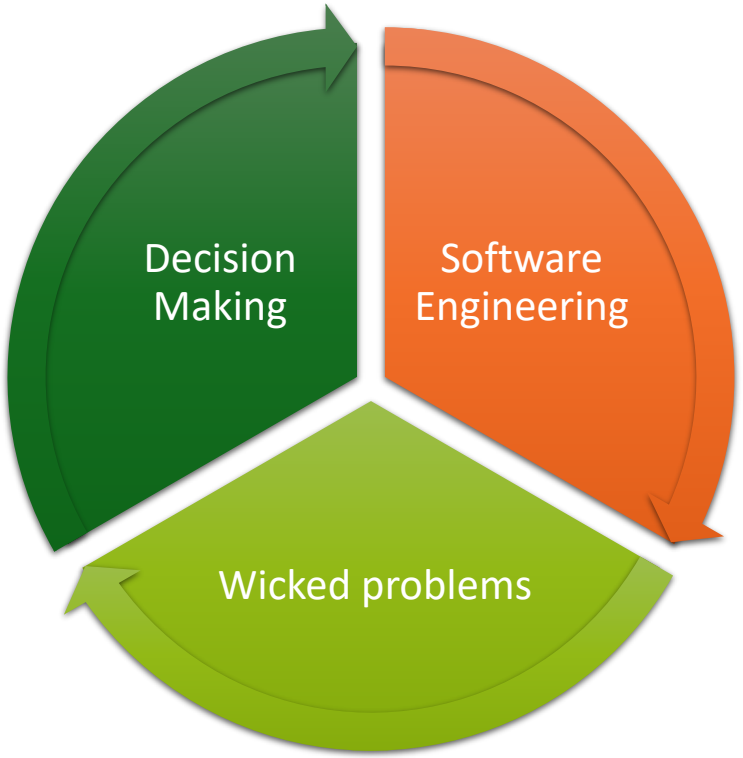
MDE has delivered value for software development – especially greenfield

MDE can still add value today but it's about time to enhance the canvas from software [development] to systems

- Software modernization
- Complex system of systems
- Decision making
- Learning-aided adaptation

LLM + MDE form a symbiotic relationship

Early results are promising but it's a long road ahead



Thank you

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