FIAS Frankfurt Institute for Advanced Studies

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Systems Science and Engineering for Intelligence

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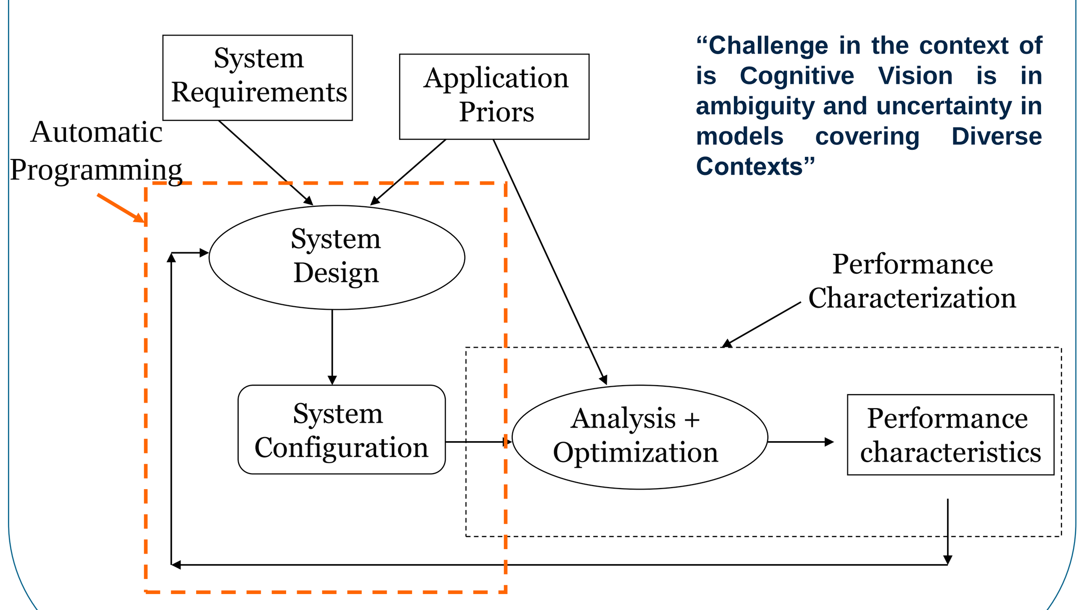
Abstract

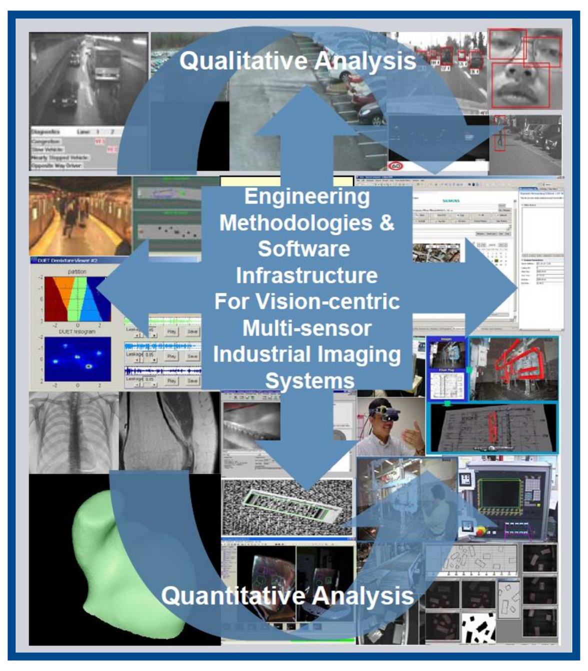
Our initiative, seeded by funding from the BMBF for the Bernstein-Focus in NeuroTechnology (2009-2016), focuses on trans-disciplinary systems research linking insights from systems engineering, neuroscience, and cognitive science/psychology. Our emphasis is on methodologies, platforms, and tools leading to safe, certifiable AI systems. We view the human brain as an evolved system, with a flexible learning architecture designed by nature to solve a range of specific tasks in a class of environments that enhances the survival of humans. Model-driven systems engineering is a discipline that formalizes application domain specification, i.e. task performance requirements and contextual models, and translates them into system designs. Systems engineering in the context of computer vision has its origins from the early 90's and has been refined over the years through practice [1, 2, 4]. At a high-level, the architectures inspired from systems engineering principles have parallels to models of brain function. The system is massively parallel and perform feed-forward decomposition of input visual signal into constituent modalities (e.g. color, motion, texture, shadow, reflection, contours, etc.) thus allowing for efficient indexing into a rich memory structure. Generated hypotheses can then be refined via a dynamic, recurrent process to converge to an interpretation. While both engineering and brain science views ([13]) of the architectures agree at this higher level, ongoing work is on engineering platforms to facilitate rapid design and validation of real-world applications. Our framework allows for parallel execution and exploration of the tradeoffs and systematic fusion of model-based and modern deep machine learning approaches to address context-sensitivity, explainability, and various degrees of safety.

Systems Engineering for Vision* (Academic Foundations – 90's)



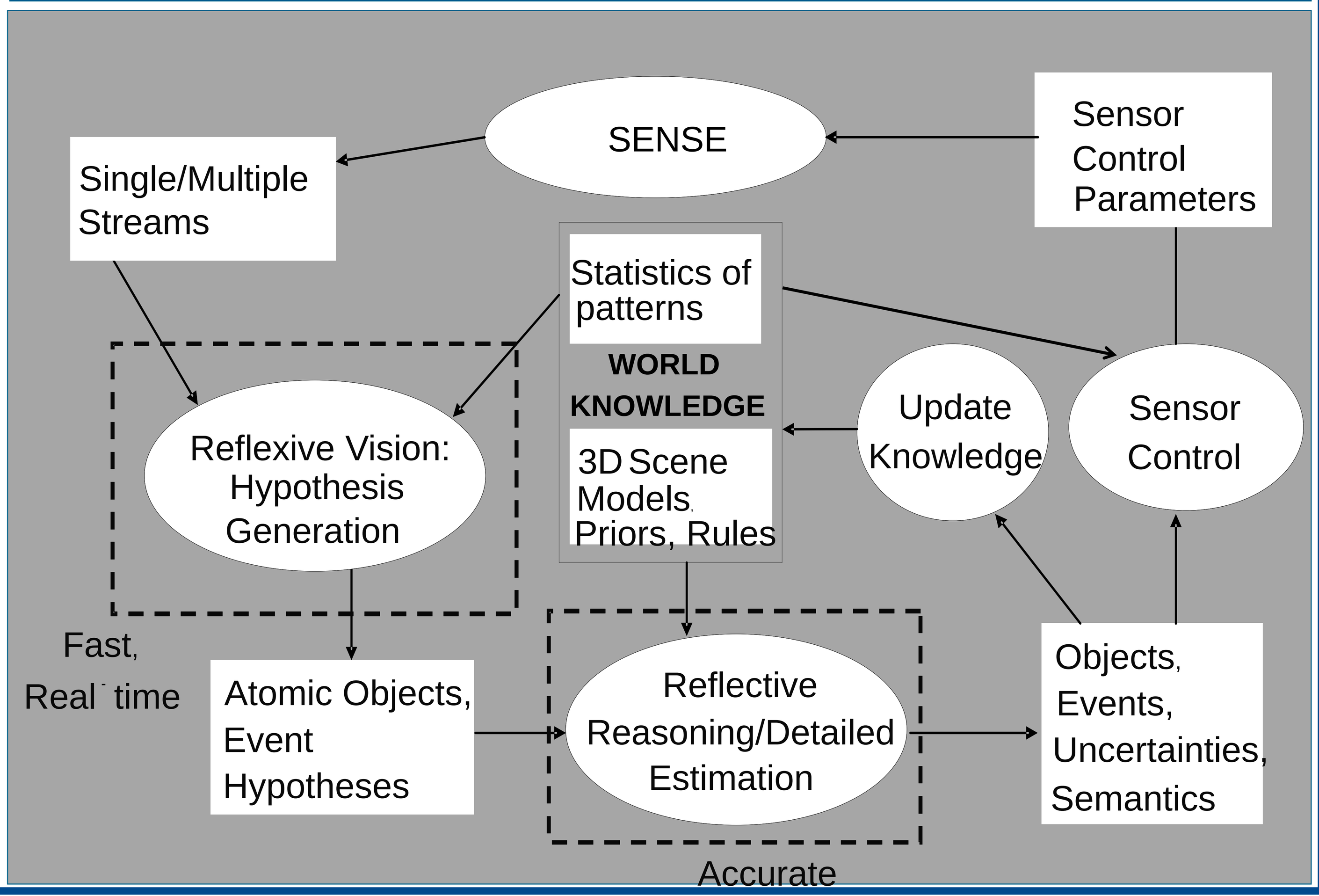
"Challenge in the context of is Cognitive Vision is in ambiguity and uncertainty in models covering Diverse Contexts"

Industrial Applications* (2000's)

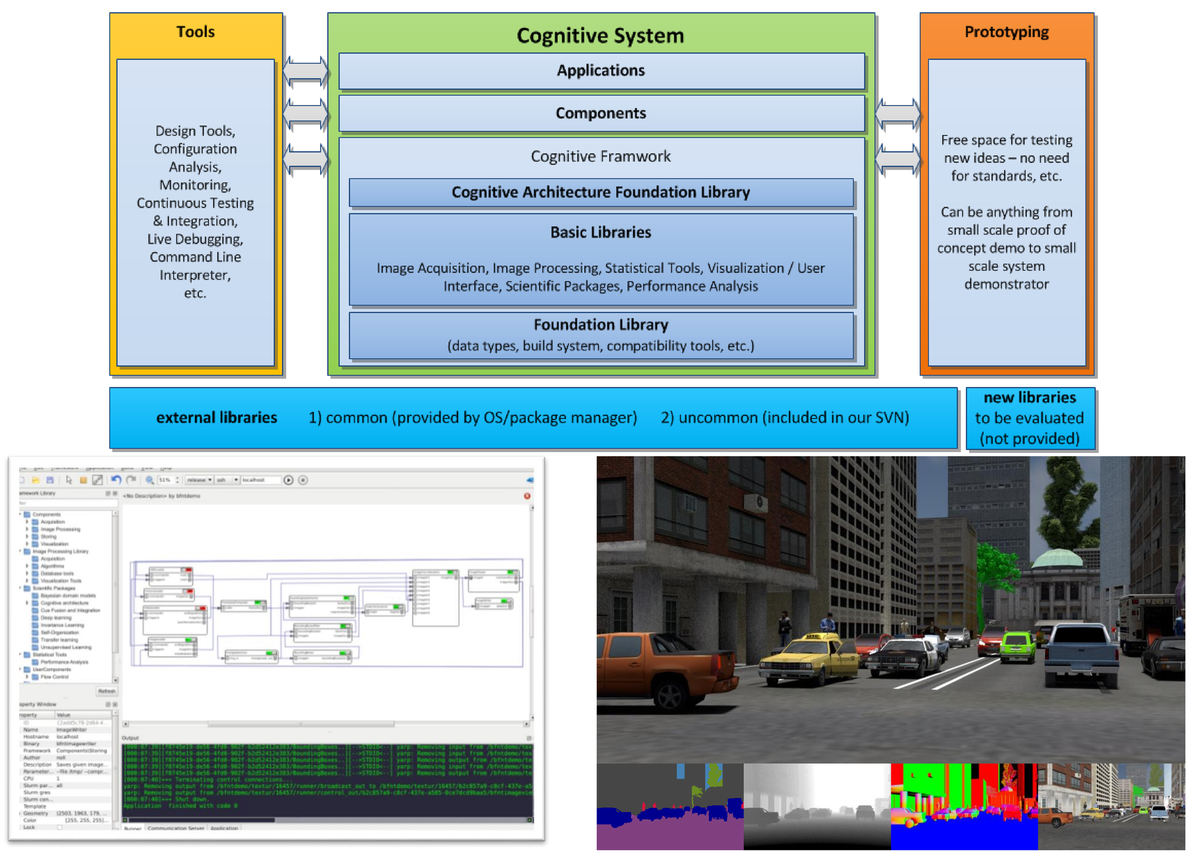


"Visual Cognition is '**quasi-invariant Indexing**' followed by **detailed estimation (or deliberation, iteration)** – open research is on systems level questions such as: **architectures, continuous learning and self-diagnostics**".
Essence of Design Framework: {Application contexts} x {questions/tasks} x {perf specs/requirements} ----> {sensor configurations} x {cognitive software: {specific hypotheses generators} + {reasoning / optimization engine} }

Cognitive Architecture

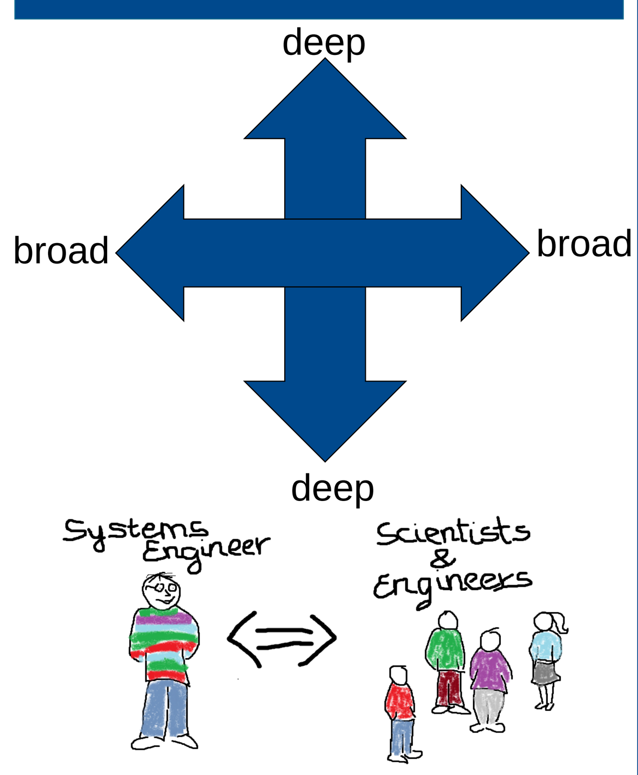


Systems Engineering Tools



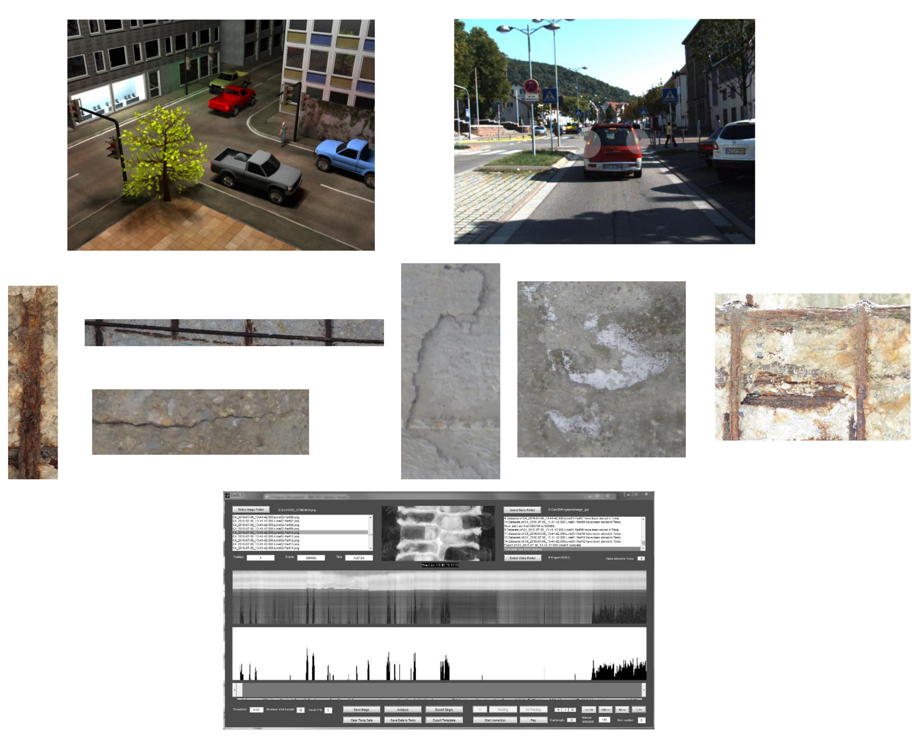
Platforms for rapid prototyping and evaluation, Simulation for visual learning, performance characterization.

Education



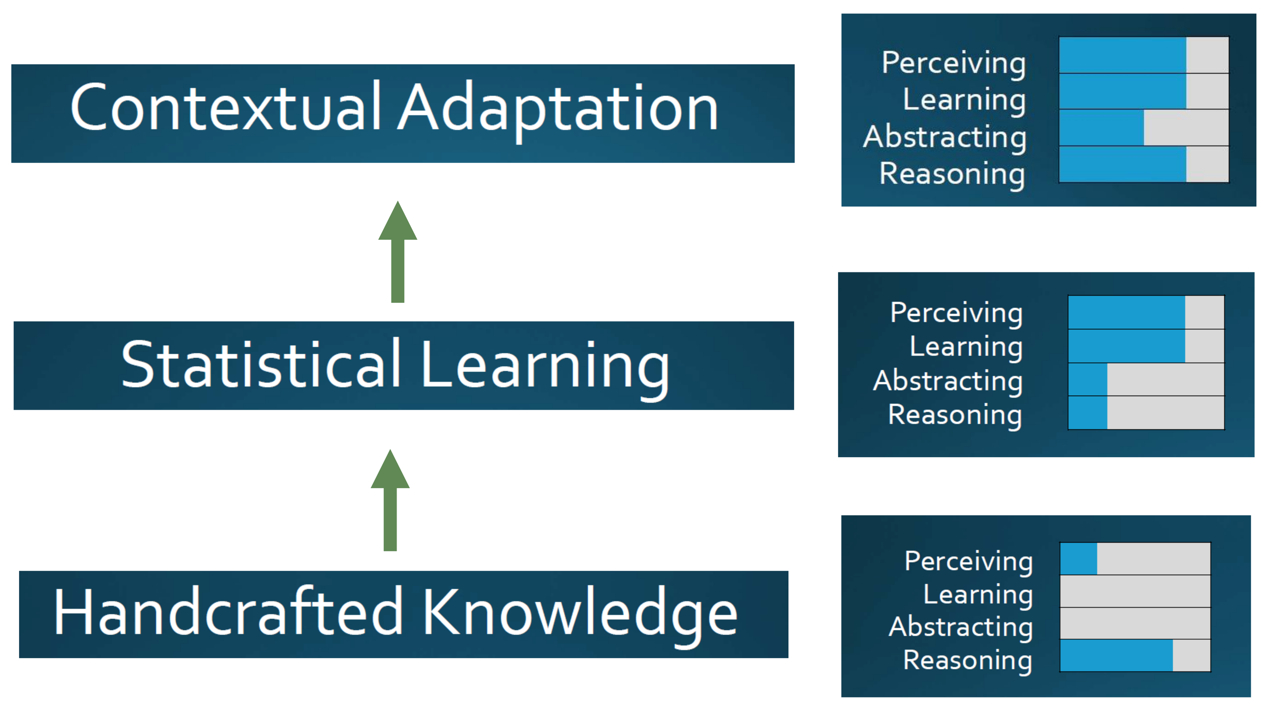
Structured curriculum for Systems and Software Engineering for Intelligence

Application: Cognitive Anomaly extraction



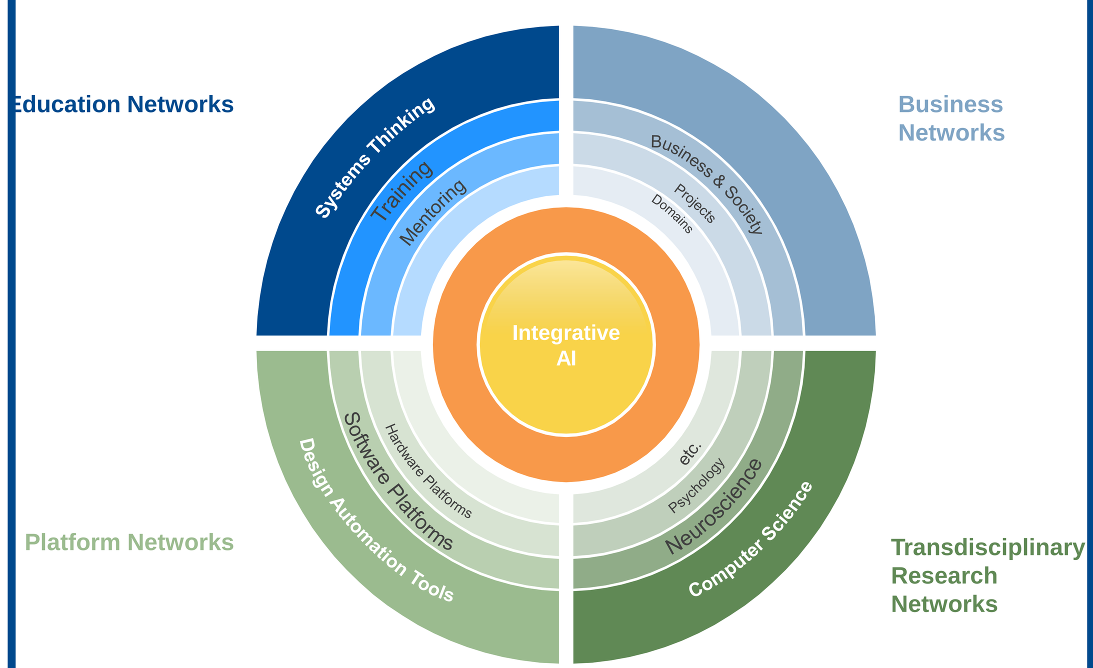
Model-based and Data-driven designs have been combined for demonstrating how expectation models in context can be used for monitoring behaviors and identify anomalies: e.g. For security, brake-light on/off detection in automotive, fine crack/defect classification in bridge infrastructure, and behavior monitoring in scientific applications.

Waves of AI (DARPA, 2017)



Paradigms for AI: Rule based systems (in the 90's) exploit **reasoning** along with limited perception. Statistical learning systems (in the 2000's) exhibit perception as well as **learning** with limited abstraction/reasoning. They have high statistical performance, but are brittle in instances and are opaque The next wave is on systems that exhibit **context-sensitivity** and have **explainability**.

AI Ecosystems



AI eco-systems are transdisciplinary. Key gaps are in: a) platforms that can enable creation of safe and explainable AI systems, b) training, mentoring of systems thinkers and c) establishment of integrated eco-systems for rapid AI innovations.

Business start up to address gaps in platforms for safe AI & training:

Objectives
⇒ Rapid creation of AI systems and solutions
⇒ Link with an eco system for safe AI
⇒ Address gaps regarding technology, talent, & costs)

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