Perception-Dominant Control Types for Human/Machine Systems

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Abstract

We explore a novel approach to complex domain modelling by emphasising primitives based on perception. The usual approach either focuses on actors or cognition associated with tokens that convey information. In related research, we have examined using *effects* and/or *outcomes* as primitives, and influences as the generator of those outcomes via categoric functors.

That approach (influences, effects) has advantages: it leverages what is known and supports the expanded logics we use, where we want to anticipate and engineer possible futures. But it has weaknesses when placed in a dynamic human-machine system where what is perceived or assumed matters more than what is known. The work reported here builds on previous advances in type specification and reasoning to 'move the primitives forward' more toward situation *encounter* and away from situation *understanding*.

The goal is in the context of shared human-machine systems where:

- reaction times are shorter than the traditional ingestion/comprehension/response loop can support;
- situations that are too complex or dynamic for current comprehension by any means;
- there simply is insufficient knowledge about governing situations for the *comprehension model* to support action; and/or,
- the many machine/human and system/system interfaces that are incapable of conveying the needed insights; that is, the communication channels choke the information or influence flows.

While the approach is motivated by the above unfriendly conditions, we expect significant benefits. We will explore these but engineer toward a federated decision paradigm where decisions by local human, machine or synthesis are not whole-situation-aware, but that collectively 'swarm' locally across the larger system to be more effective, 'wiser' than a convention paradigm may produce.

The supposed implementation strategy will be through extending an existing 'playbooks as code' project whose goals are to advise on local action by modelling and gaming complex system dynamics. A sponsoring context is 'grey zone' competition that avoids armed conflict, but that can segue to a mixed system course of action advisory. The general context is a costly 'blue swan' risk in large commercial and government enterprises.

The method will focus on patterns and relationships in synthetic categories used to model type transitions within topological models of system influence. One may say this is applied intuitionistic type theory, following mechanisms generally described by synthetic differential geometry. In this context, the motivating supposition of this study is that information-carrying influence channels are best modelled in our challenging domain as *perceived* types rather than *understood* types.

Structure of the Study

We work with scenarios, starting simply and leveraging ontic metaphors where possible. Our group tackles usually unaddressable problems by using type engineering and novel logics. It is quite easy to lose architectural focus in these explorations, in part because many of the components or abstractions have attractive benefits worth exploiting but they also blur the focus. A tendency is to serve different needs wherever it seems convenient rather than engineering the type and abstraction systems for the intended disruptive capability.

An approach is to define the desired disruptive capabilities, engineer the novel abstractions, types, and logics to suit, and only then decide what parts of the system support what tasks. This paper explores the advantage of using 'perception' and 'intent' as the key properties in advising a system architecture in this way. To our knowledge these have not been employed as essential primitives, and the abstraction architectures they indicate would not be otherwise intuited.

Our general goal is practical open-world reasoning, inspired by the original goals of situation theory. Statements are interpreted within situations, and as that situated influence changes, the statements change in fundamental ways. We believe modelling *influence* is a reasonable approach; the paradigm is simple: situations in some combinations affect the meaning of a fact, statement, or state, and that now is part of a situation that influences things

downstream. Influence is thus the primary connective in the model, and any intermediate or final result, usually characterised as a state in a narrative, is an outcome of a complex dynamic fabric of influences.

A complication is that, at least in human reasoning, we apply situated influence to statements as a normal process of interpretation, and we seem not worried if the situations have intrinsic salient unknowns, or suddenly salient unknowns. In other words, we do *open world reasoning* with regard to situations, and happily accommodate, even entertain unknowns in those situations. An example we have used before are some narrative fragments starting with 'the Baby cried.' Assume we have a person that is in a situation and the only information they have about that situation are text fragments. The first statement they get is, "the Baby cried."

Most possibly, the associations will be of a vulnerable being in ordinary distress. Because babies are seldom unaccompanied, the imperative to act will be low and this will likely be registered as merely an observation of the environment. If we knew, for instance that the situation was the evacuation from a fire, this fact may be of profound interest, but in this example our person has no such cue. If this were a written fragment, our observer may notice the upper case of "Baby" which assumes a previously known identity.

Now consider a second fragment: "The Mommy picked it up." This additional information invokes a situation that resolves the latent possibility of intervention because a Mommy has done so. We have just had a narrative with some unresolved tension in a situation and a resolution. As before, the upper-case assignment infers but does not guarantee that the Mommy's identity is previously known. It could infer that the mother is singularly the Baby's mother.

A third fragment: "The Mommy hit the Baby." We may be now alarmed, having adjusted the original situation from one of possible intervention to resolution, and now to more intensive concern and possible action. Specifically, a normal, healthy parental relationship has turned ugly, with a possible presumption (again with no guarantee) that the child was upset because of abuse. The example continues with another context shift where the food stuck in the Baby's throat comes up and its life is saved.

Our considerable study of this simple example will be presented in two forms. The first is our model of influence as cognitively understood (by the observer) that leads to possible futures and actions. This 'possibility model' is the first we know that is supported by formal functorial definitions and that maps back to conventional, ontologically-informed knowledge stores. With this background, we will remodel the example from cognitive types, functors and topologies to perceptive types. Our expectation is that the contrast between these models will indicate not just differences but formal challenges and benefits. Then we will work through three perception-centric real-world examples.

The most developed is an advanced risk modelling use case for commercial enterprises with the intent of mitigating harm to humans from vehicles. A complication in this example is that enterprises own the problem and need to be the primary actors in setting policies, but the perceptive processes we are modelling are of individuals entailed in incidents. We intend this example to inform and improve safety in target domains in the short term; i. e., one year.

This second case has a three-year horizon. The world of interest is the palette of options a nation will have to preserve the world order, ensuring safe commerce and national independence. This includes diplomatic and economic actions as well as military deployments and exercises. Included is so-called defensive information (or 'cognitive') warfare, meaning positive action to ensure truth dominates a healthy public discourse. Within this large international system, we will focus on immediate actions, those that will take two hours or fewer to effect — much too short for a multi-enterprise cognitive-centric collaboration.

Our goal in this study is a better understanding of what to simulate and game over a large number of iterations to produce 'plays'. These are actions that are tied to perceptive profiles and might be characterised as 'if this topology of influence presents, with that topology of undesirable outcomes, take so-and-so action.' The interesting challenge of this case study is the direct coding within executable simulation environments. This is not just a navigable model, but an executable, introspective, synthetic world of perceptive asterisms, functorial effects, and multiparty affordances.

Our third and most detailed case study will be the enhanced carbon uptake in the biosphere by a supposed human-machine-biota, enhanced/engineered pollination system We will model complex ecological systems and their enhancement through local perceptive mechanisms of multiparty sexual reproduction (primarily pollination via bees, birds, and robotic surrogates).

Aside from having more layers of agency, and more complex success factors, the motivating factor in this study is not merely understanding the fabric of perception and benefit. We want to also model the forces that *produce* the perceptive mechanisms because that is where potential engineering affordances will have the greatest effect. A motivation is that our primary task is abstracting from observation to some controlling world dynamics. If sight is a core capability in enabling pollination, what are core capabilities and influence mechanisms in enabling sight? And can we model arbitrarily high layers of type abstraction using the same metaphors of perception? This third case has a longer-term perspective.