mode (e.g. visible, invisible, observed, observable, etc.) or an abnormal (e.g. pathological) characteristic.

The above remark clarifies the generality of the modeling framework. In order to broaden its scope, we should add that a *Proposition* can be the result of particular *Reasonings* or indeed *Communications* when a *Message* is transmitted between agents. The expressions "empty fuel tank hypothesis" and "low battery level complaint" can thus be likened to *Propositions* resulting respectively from hypothetical *reasoning* and a discursive act consisting in "complaining about something".

In order to further emphasize the generality of this modeling framework, we note finally that a model (for example a *CarModel*) can be likened to a *Proposition*. This category covers knowledge models exploited by *Reasonings* as well as mathematical models used to simulate system behavior.

Participation modes

However general it may be, the framework outlined so far remains incomplete because it does not allow us to account for expressions like "diagnosis hypothesis", "model to calibrate" or "calibrated model". This type of expression - useful for naming *knowledge roles* (in the CommonKADS sense) in task inputs and outputs [4] refers, in fact, to ways in which *Contents* participate in *Reasonings*, for example as data or results. This "participation mode" domain is covered by a specific OntoKADS component - a sub-ontology of "participation roles".

These roles (also referred to as "casual roles" or "thematic roles" in the literature) are defined in OntoKADS as particularizing the endurant concept. In fact, DOLCE's axiomization assimilates the notions of *endurant* and *participant*[15]. Hence, the participation roles or specialized participants are defined by introducing relationships which particularize the *PC* participation equation.

In this section and by way of illustration, we shall define first the *Patient* role using the *isAffectedBy* relation (A10)(D3)(T1) and then the specialized *Data* role using the *isDataOf* relation (A11-13)(D4)(T2-3). It is noteworthy that we have forced the *Data* i) to be a *Content* participating in an *Action* (A12) and ii) to participate from the start of the perdurant onwards (A13) (in contrast, the *Result* participates at the end of the perdurant). Finally, *CalibrationData* is defined as data for a particular *Reasoning* (a *Calibrating* (D5)) and a *ModelToCalibrate* is defined as a *Model* playing the role of *CalibrationData* (D6).

(A10) $\text{isAffectedBy}(x,y) \rightarrow \exists t(\text{PC}(x,y,t))$

(D3) $\text{Patient}(x) =_{\text{def}} \exists y(\text{isAffectedBy}(x,y))$

(T1) $\text{Patient}(x) \rightarrow \text{ED}(x)$

(A11) $\text{isDataOf}(x,y) \rightarrow \text{isAffectedBy}(x,y)$

(A12) $\text{isDataOf}(x,y) \rightarrow \text{Content}(x) \wedge \text{Action}(y)$

(A13) $\text{isDataOf}(x,y) \rightarrow \exists t \forall t'((\text{PRE}(y,t') \wedge t' \leq t) \rightarrow \text{PC}(x,y,t'))$

(D4) $\text{Data}(x) =_{\text{def}} \text{isDataOf}(x,y)$

(T2) $\text{Data}(x) \rightarrow \text{Patient}(x)$

(T3) $\text{Data}(x) \rightarrow \text{Content}(x)$

(D5) $\text{CalibrationData}(x) =_{\text{def}} \exists y(\text{isDataOf}(x,y) \wedge \text{Calibrating}(y))$

(D6) $\text{ModelToCalibrate}(x) =_{\text{def}} \text{Model}(x) \wedge \text{CalibrationData}(x)$

The modeling primitive: *KnowledgeRole*

In our modeling of *Reasonings*, we were careful to characterize separately the nature of the participating entities on one hand and the nature of the participation modes on the other. In the CommonKADS method, this distinction reflects the difference between two modeling primitives, the "domain concept" primitive and the "knowledge role" primitive. In this section, we focus on the latter by showing how it can be ontologically founded. We end by defining novel modeling primitives for the OntoKADS method.

To achieve this, we have adopted the ontology of meta-properties defined in [12] as our reference framework. We also adopt their definition of three meta-properties involving the notion of "role": *role*, *formal role* and *material role*.

- A *role* is an *anti-rigid*[16] concept which depends on an external entity. Its *anti-rigidity*, (i.e. the property of being non-essential for all its instances) translates into dynamic behavior over time: an instance only plays a role by accident. Its *dependence* translates the fact that playing this role (for a given instance) necessarily implies the existence of another (external) instance.
- A *formal role* is a *role* which does not carry an *identity criterion*. A *formal role* restricts itself to characterizing a dependence mode vis-à-vis another entity, without constraining the identity of the entity playing the role. The *Agent* and *Patient* concepts (which we qualified as "participation roles") are examples of formal roles. At the beginning of this article, we notably saw that *agentives* possessing very varied *identity criteria* can play the role of *Agent*.
- A *material role* is a role carrying an *identity criterion*. A *material role* is usually subsumed by a *formal role* (from which it inherits its anti-rigidity and external dependence properties) and by a *type* (from which it inherits an *identity criterion)*. Examples of material roles are the *Student* and *Employee* concepts defined as *Per-*

[15] According to DOLCE axioms: Ad33 ($\text{PC}(x,y,t) \rightarrow \text{ED}(x) \wedge \text{PD}(y) \wedge \text{T}(t)$) and Ad35 ($\text{ED}(x) \rightarrow \exists y,t(\text{PC}(x,y,t))$), only the endurants participate in the perdurants and, incidentally, all endurants participate necessarily in a perdurant.

[16] For reasons of space, we are not able to give the notions' formal definitions here. The reader is invited to refer to [12].

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