# The BAALL Ontology – Configuration of Service Robots, Food, and Diet

Bernd Krieg-Brückner[1,2], Serge Autexier[1] and Mihai Pomarlan[2]

[1] *German Research Center for Artificial Intelligence, DFKI, BAALL, Bremen, Germany*
[2] *Collaborative Research Center EASE, Universität Bremen, Germany*

**Abstract**

The BAALL Ontology, originally motivated by Ambient Assisted Living, now comprises more than 40k OWL axioms to integrate diverse applications, covering a foundational, a variety of general, and several application domain ontologies for configuration of service robots, diets, structured food products and dishes, and cooking assistance. To maintain structural consistency, *safe ontology extension* is supported by Generic Ontology Design Patterns.

**Keywords**

service robots, food, diet, generic ontology design patterns, qualitatively graded relations

## 1. Introduction

The BAALL Ontology has been developed at DFKI's *Bremen Ambient Assisted Living Lab, BAALL*, the original work on configuration of mobility assistants (cf. Sect. 3) being motivated by AAL. Its domain has since been extended to cover configuration of diets (cf. Sect. 4) and robotics, food products and dishes (cf. Sect. 5), cooking assistance (cf. Sect. 6), and support for service robots (cf. Sect. 7)[1]. It now comprises more than 40k OWL axioms; thus *structuring* (cf. Sect. 2) and *safe extension* (cf. Sect. 8) are essential.

## 2. Structure, Foundation

**DUL and DULsineA.** Consider Fig. 1: the BAALL "hyper-ontology" is modularised into separate ontologies with import relations. Via the module Foundation, compatibility with DUL is maintained. DUL, DOLCE Ultra Light (see www.ontologydesignpatterns.org/ont/dul/) is based on the "Upper Ontology" DOLCE, providing *universal concepts* as a common ground. DUL is not used directly, but abstracted to DULsineA ("without axioms"), a version of DUL stripped of most relations and axioms, but keeping the essential structuring categories. New

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Bernd.Krieg-Brueckner@dfki.de, bkb@uni-bremen.de (B. Krieg-Brückner); Serge.Autexier@dfki.de (S. Autexier); Mihai.Pomarlan@uni-bremen.de (M. Pomarlan)

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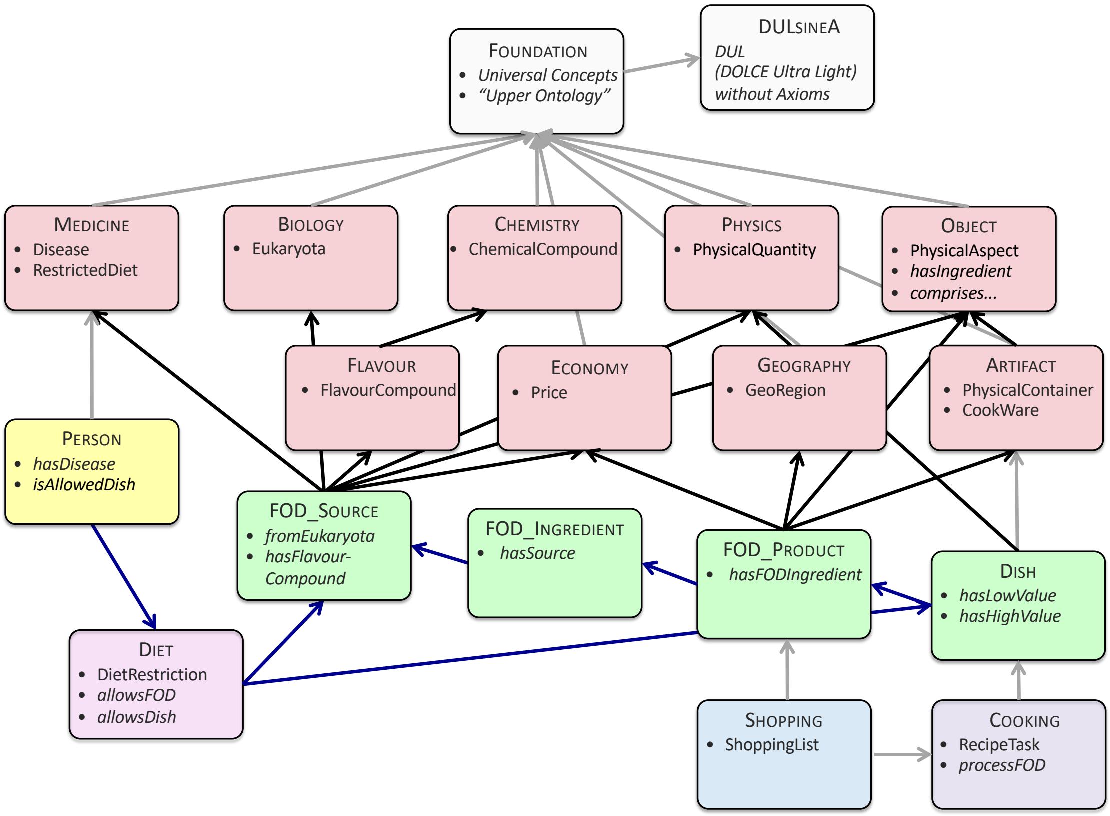


**Figure 1:** Structure of the BAALL Ontology, with import relations

categories, characteristic relations, and axioms are only introduced by Generic Ontology Design Patterns when required, cf. Sect. 8.

## 3. Configuration of Mobility Assistants

The BAALL Ontology was motivated by the project *Assistants for Safe Mobility* (ASSAM, www.assam-project.eu) [1], where multifaceted variants of smart mobility assistants have been developed on the basis of wheelchairs and walkers. These are intended to compensate for individual age-related impairments: end-users may be afflicted by diseases leading to motoric impairments (e.g. loss of endurance, visibility) or cognitive impairments (e.g. disorientation). With appropriate hardware/software components, the mobility devices not only compensate for motoric impairments, but also provide orientation and navigation assistance. This variety is a considerable challenge for assessment and configuration.

About 25 separate interlinked *general domain ontologies* have been developed (the layer below Foundation, coloured red in Fig. 1) such as Medicine defining Disease, or Artifact defining MobilityDevice as a subclass of Device.

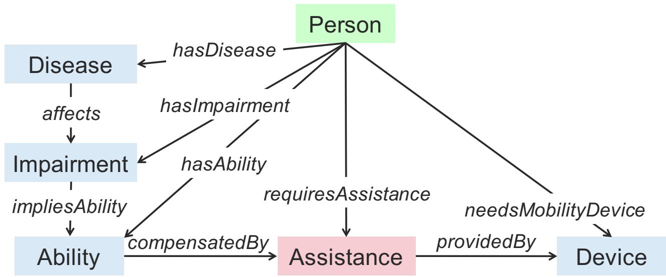


**Figure 2:** Composite configuration for Person needsMobilityDevice MobilityDevice

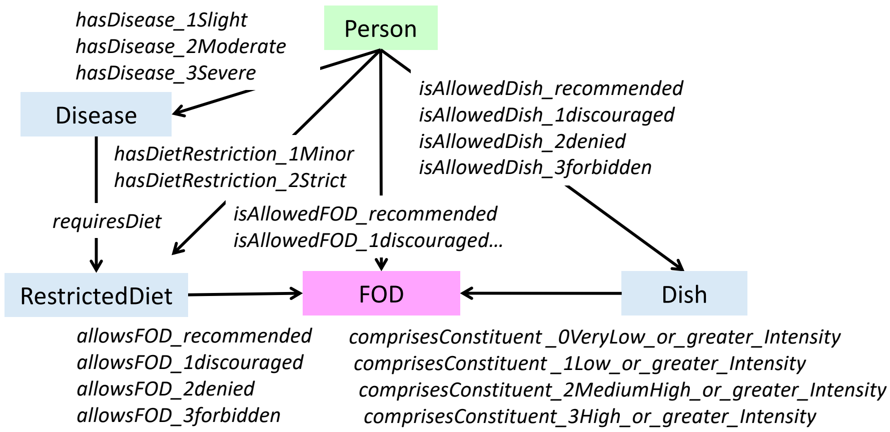


**Figure 3:** Configuration of Diet

**Composite Configuration.** To manage complexity, the relation needsMobilityDevice (Fig. 2) is a stepwise composition of individual relations from Person to separately defined ontologies. Individual Diseases of a particular Person are assessed, captured by the relation hasDisease. A Disease may result in some Impairment modelled in the relation affects. In turn, an Impairment impliesAbility an Ability; an Ability may be compensatedBy some Assistance providedBy some MobilityDevice. For Disease, Impairment, etc., see [2].

Thus the relation needsMobilityDevice is sequentially composed, where each relation is a "triangular" composition, e.g. requiresAssistance ∘ providedBy → needsMobilityDevice.

It is sufficient to model the individual relations affects, impliesAbility, etc., *separately*, and once and for all; the rest is deduced by OWL-DL reasoners.

## 4. Configuration of Diet: Qualitatively Graded Relations

Similarly, the left-hand side of the diagram in Fig. 2 has been re-used and refined for the configuration of diets, see Fig. 3.

To achieve a graded valuation according to some qualitative abstraction of a semantic concept, we introduce extra valuation domains with values such as 1Slight, 2Moderate, 3Severe, or some other (arbitrarily fine) qualitative metrics; the number of levels depends on the application. *Qualitatively graded relations* (cf. [2, 3, 4, 5]) encode such valuations in the names of (a sheaf of) relations hasDisease_1Slight, hasDisease_2Moderate, etc.

## 5. Structuring Food Products and Dishes

In the case of diets, the object to be configured is Food or Drink (abbreviated as FOD in Fig. 3); a Person is recommended, ..., or forbidden certain FOD, e.g. food products containing PorkMeat, or pungent dishes for Gastritis or certain allergies.

To facilitate such a modelling, the ontologies containing FOD and Dish are structured in an onion-like fashion (Fig. 1): FOD_Source is the core, where e.g. PorkMeat is characterised as isCutOf **some** Pig and fromAnimal SusScrofaDomesticus in the Biology ontology. Similarly, FOD_Ingredient relates to FOD_Source only by the relation hasSource, and FOD_Product to FOD_Ingredient by hasFODIngredient. A particular PungentDish can now be defined by comprisesConstituent_2MediumHigh_or_greater_Intensity **some** PungentFlavourCompound, etc. (Fig. 3). The BAALL Ontology is categorized on the basis of Eurocode-2 (EuroFIR), with constituent relations to Aromas, the usual NutritionCompounds, and FoodAdditives (according to the International Numbering System, INS).

## 6. Cooking Assistance

Early work on cooking assistance [3] has led to comprehensive modelling of Ingredients (cf. Sect. 5). A recipe is a workflow of RecipeTasks such as preparation, baking, etc. *Cooking* is modelled based on Ingredients with e.g. flavour properties, while RecipeTasks modify their presence, e.g. when an aroma evaporates at a particular temperature. We hope to be able to eventually predict a flavour composition in the final dish by “virtual cooking”.

## 7. Organizing Knowledge for Robotic Activities

The device configuration from Sect. 3 has later been refined by qualitatively graded configuration (Sect. 4) and become the basis for configuration in robotics, sharing user and device profile modelling, cf. [4].

The structure of an *episodic memory* has been formalised for domestic service robots performing everyday activities (see [5]) by an ontology engineering effort undertaken by the EASE[1] project, resulting in a set of ontologies referred to as SOMA [6]. The focus of SOMA is autonomous and cognitive robotics, a still emerging field, which differentiates it from the more industrially focused effort at standardizing robotic knowledge representation undertaken by the ORA group [7]. Researchers involved with the development of SOMA have built upon knowledge and patterns formalized in the BAALL Ontology.

An important use of episodic memories is to provide training data for a robot to improve its performance—either by learning from its own activities, or from observing (records of) the activities of other agents, e.g. humans demonstrating how a task should be performed. An episodic memory must be organized so that it will contain at least some useful knowledge for an observing agent, even if the recording agent is different in body and capabilities. Therefore it contains views on an activity from different levels of abstraction, from recordings of sensor inputs and control signals, close to the hardware, to more cognitively motivated sequences of tasks in which entities in the world play roles while obeying restrictions pertaining to the task, or placed on the entities by their own dispositions and/or capabilities. At this cognitive level the rich ontology of RecipeTasks and Cookware from the BAALL Ontology is put to use in EASE's episodic memories.

Gathering a rich variety of episodic memories requires an interdisciplinary collaboration among roboticists, cognitive scientists, and neurologists in EASE[1]. This places further critical requirements on the knowledge infrastructure that processes episodic memories. In particular, there must be ways to verify that episodic memories entered into storage obey logical constraints on what is a well-formed episode recording; also important is to check whether an episode recording represents a "good run" of an activity – episodes of failure are an interesting source of learning, as long as failure is recognized as such [5].

## 8. Safe Extension Using Generic Ontology Design Patterns

Episodes and the other patterns above have been defined by *Generic Ontology Design Patterns*, GODPs [2, 4, 5, 8], expressed in the language Generic DOL [9], an extension of the *Distributed Ontology, Model and Specification Language*, an OMG standard (see omg.org/spec/DOL, dol-omg.org), supported by the *Heterogeneous Tool Set*, Hets [10].

GODPs structure complex ontologies, with local confinement of design choices, ensuring safety for modelling *and* data with sanity checks on their input and generative internal consistency for their interrelation. Thus they are very useful for maintaining *structural consistency* in extensions of large ontologies, even by non-experts.

We may e.g. define a pattern to extend FOD_Source with a new fish while relating it to its counterpart in the Biology ontology; this anchor is important for correct translations to common names in other natural languages, a likely source of error.

## 9. Conclusion

The BAALL Ontology is primarily used for semantic integration. Depending on the application, several application domain ontologies provide restricted "views" to the structured hyper-ontology (cf. Fig. 1). As examples consider Person importing Assistance and Artifact for MobilityDevice on the one hand (cf. Sect. 3), or Person importing Medicine and Diet on the other (cf. Sect. 4). Assistance for mobility devices, FOD, Diet, RecipeTask and Cookware provide a fair coverage for extensive academic use; completeness for commercial use is not claimed.

The structured BAALL Ontology and some examples of application domain ontologies derived from it can be found at http://ontologies.baall.de, freely available to the academic community, with a dual licence for commercial use.

It is presently being re-constructed by applying GODPs in a systematic fashion (cf. Sect. 8). GODPs also support populating the BAALL Ontology by data in a safe way (cf. Sect. 8 and [5]), e.g. for robot or human activity recordings (cf. Sect. 7), or for specific food products and dishes (cf. Sect. 5).

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