Data Models for Home Services

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Abstract

An ultimate penetration of communication technologies allowing web access has enriched a conception of smart homes with new paradigms of home services. Modern home services range far beyond such notions as Home Automation or Use of Internet. The services expose their ubiquitous nature by being integrated into smart environments, and provisioned through a variety of end-user devices. Computational intelligence require a use of knowledge technologies, and within a given domain, such requirement as a compliance with modern web architecture is essential. This is where Semantic Web technologies excel. A given work presents an overview of important terms, vocabularies, and data models that may be utilised in data and knowledge engineering with respect to home services.

Index Terms: Context, Data engineering, Data models, Knowledge engineering, Semantic Web, Smart homes, Ubiquitous computing.

I. INTRODUCTION

In recent years, a use of Semantic Web technologies to build a giant information space has shown certain benefits. Rapid development of Web 3.0 and a use of its principle in web applications is the best evidence of such benefits. A traditional database design in still and will be widely used in web applications. One of the most important reason for that is a vast number of databases developed over years and used in a variety of applications varying from simple web services to enterprise portals. In accordance to Forrester Research though a growing number of document, or knowledge bases, such as NoSQL is not a hype anymore [1].

All the database design approaches have something in common: notions that are introduced as concepts, entities, subject, objects, instances, or somehow else – depending on a design. Another important similarity – relationships between notions and their properties. However, ways to define those are different. Taking into account that an ability of a system to process data from the other system is one of the most crucial points of interoperability, data integration has always been a challenge. Semi-structured and structured data has been found to be relatively easier integrated than a raw data [2][3]. Structuring data allows loose the coupling and semantics. In accordance to [4], a data model defines the structure and meaning of data.

Even though such definition limits a scope of data models to conceptual view, partially consider logical and leave outside the physical view, one may agree that in a mark-up world of web flat or raw data is not the main major exchange. Because of a scope of this document, the overview of data models will briefly start from the Database Model and gradually move towards the Semantic Data Models, to which the biggest attention will be given.

A. Service Delivery Paradigm

The boundaries of this work are determined by a domestic services domain, where retailers, service providers, content suppliers, business entities, public authorities, and other involved stakeholders assist an independent living of domestic users by maintaining a high quality of life. A service delivery paradigm describing such ecosphere has been presented in [5]. ICT Home Services are relevant to activities of such stakeholders as service providers and content suppliers for delivery of value-added services to modern households residing the UHE [5]. Under a proposed vision, a central part of the ecosystem is the *Ubiquitous Home Environment* (UHE), which is a user-centric set of systems that serve users in domestic environment and expanding its services to public and professional environments [5].

UbiHomeServer [6] is the implementation of the UHE serving engine developed by Oulu University of Applied Sciences (OUAS) group at PBOL. The UbiHomeServer offers a set of GUIs through which it is possible to interact with the UHE as well as consume and manage some of the ICT Home Services [5]. The UbiHomeServer operated GUIs offer similar user experiences regardless of a category of a terminal device and thus form an identical front-end of the UHE. A main view of the UbiHomeServer front-end is shown in the Fig. 1 [5].

Fig. 1. Main View of the UbiHomeServer GUI

Clicking to an active button brings a chosen service interface that is implemented in a similar way as main view, and has own set of options. One off the options allows removal of currently invoked service to a service basket. Thus the removed service disappears from main menu, but occurs in the service basket – and can be retrieved from there back to the main menu.

With respect to interoperability, the following service categories were defined [5]:

- Informative – one-way data flow from service provider or content supplier to
- Interactive – request-response model allowing purchase orders using a single customer ID from a single household.
- Fully interactive – advanced version of previous, allowing purchase orders using multiple customer IDs from multiple locations, taking into account a variety of preferences and customizations.
- Ultimate – is achieved using a variety of architectures, communication channels and protocols simultaneously.

Two groups of scenarios under which all the ICT Home Services may happen [5]:

1) Call-for-services scenario. All newly-proposed services are automatically discovered and presented to the end-user via the UbiHomeServer GUIs. End-users may use interfaces of once- or periodically-occurred services (such as request for a transportation, refrigerator filling), or apply for scheduled services. Certain functionality may also allow a simplified way to expand/update or cancel/reschedule the services (cleaning, pushing snow, sauna time, meal delivery). Some of the services may be invoked automatically based on data obtained from dedicated devices and/or system awareness.
2) Inter-services scenario. A company that is specialized in providing supporting services of health- and supervising-care for nursing homes through their task-management system is able to get access to the UHE data, including personal, health and locally-stored or recently-observed medical data. By using this data, company’s system may allocate tasks or initiate service request to a third company that uses the system. By providing real-time support for field workers, task-management system of that company is able to update a current state of a dedicated task with the most recent data from the UHE.

In order to implement such the ICT Home Services, a data exchange between stakeholders (their systems) and the UHE is needed. Thus, knowledge management technologies are advisable to process data, retrieve information, and build knowledge. Higher level of semantics allows more intelligence of interoperability scenarios, but there is no guarantee that information systems of stakeholders are ready to interoperate at such levels [5].

Due to a multidisciplinary of service subjects and a heterogeneity of data, only high-level notions of relevant data models are described in this document.

II. Data models

A. Database Models

Within the domestic services domain, it is essential to start with such highest abstraction notion as service. In marketing science, the service is similar to goods[7], or products, and is considered to be a part of a service-product continuum [8]. The service-product continuum assumes a variety of operations, including different forms of sales [9].

Even though database models are usually proprietary, some of them are publically available. Database Answers [10] bring samples of eighteen models relevant to services. Oracle Retail Data Model Reference describes [11] a very sophisticated Logical Data Model of *Oracle Retail Data Model* [12]. The Salesforce.com Foundation published Entity Relationship Diagrams (ERDs) describing sales objects [13].

By anything a variety of database models, it is possible to define a set of key notions for a given domain. Those notions form the highest abstraction level of the service model. The list includes the following: *Product*, *Organization*, *Person*, *Place*, and *Event*. Product notion may also express *Service*, *Item*, *Article*, or *Offer*.

Organization notion may also express *Company*, *Retailer*, *Service Provider*, or *Content Supplier*. Person notion may also express *Customer*, or rather *Client* – as individuals are consumers of the home services rather than legal entities. Place may also express *Address*. Event may express quite a large variety of notions, like *Special Offer*, *Promotion*, *Happening*, *Occurrence*, or *Incident*. In some of the models, the *Order* notion that may also express *Contract*, *Document*, or *Booking*, it may be considered as the high-level notion. In some though, it is a matter of child- or sub- relation, or is a property.

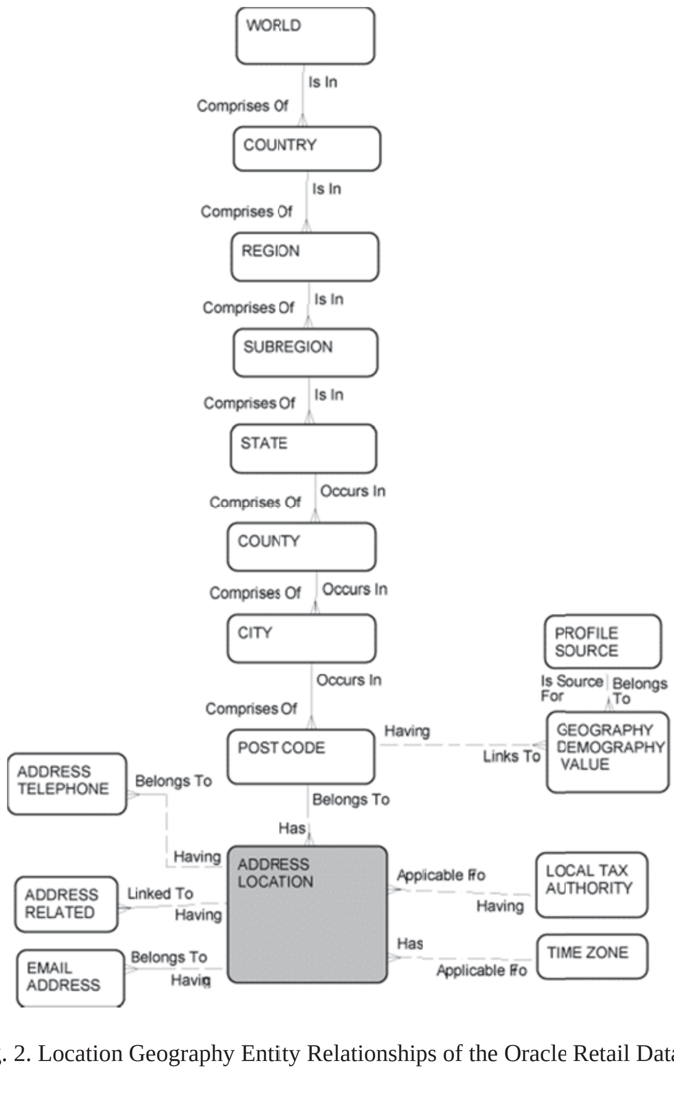

Fig. 2. Location Geography Entity Relationships of the Oracle Retail Data Model

Database models are not generic. Some parts of models though may be considered to be generic. The Location Geography Entity Relationships of the Oracle Retail Data Model [11] is presented in Figure 1. World is the top of the geography hierarchy. World is comprised of Country which is comprised of Region which is comprised of Subregion which is comprised of State which is comprised of County which is comprised of City which is comprised of Post Code which as Address Location. Local Tax Authority and Time Zone are also parents of Address Location. Post Code has Geography Demography Value, which belongs to Profile Source. Address Location has Address Telephone, Address Related, and Email Address [11].

This part of the data model is very essential and generic. Business Process models, organizational structures, a subject of services and many other influences have a strong affect to database models. The affect is magnified by a variety of implementation strategies that may bring a loss of semantics [14] in case of top-down approach while moving from conceptual schema to logical and further to physical, and impedance mismatch [15] that is a result of differences in expressive power of design approaches. That all yielded to a vast number of very specific data sets that are a big challenge for interoperability.

Speaking of modern systems, database models are good to handle application-specific or internal data of systems, for performance-crucial data, systems that do not imply a machine intelligence, or reflect a generic schema. Otherwise, operations with data may require some data enhancements like annotating, mapping, wrapping, or even very complicated knowledge-based operations that include many stages of data processing.

B. Knowledge Models

The *Ontology Spectrum* [16] describes a range of semantic models of increasing expressiveness and complexity: taxonomy, thesaurus, conceptual model, and logical theory [17]. Taxonomy is a way of classifying or categorizing a set of things in a form of a hierarchy (tree, or parent-child) and allows a syntactic interoperability [16],[17].

An attempt to generalize application-specific concepts and simplify data sharing by a use of formalized vocabulary resulted in development of generic data models. One of such models is *Gellish English* [18] that adopted STEPlib dictionary based on AP221 and ISO 15926 data models. It is the English variant of Gellish and is a structured subset of natural English that aimed to be common standard universal data model as well as a common data language for the application domains of database users [19].

The Gellish English Dictionary defines a concept by expressing a fact about the concept. That expression has the form of a specialization relation or qualification relation [20]. The facts are grouped in collections of facts that define domain specific subsets of the dictionary [20]. With respect to set of notions defined for database models, the following subjects are a matter of interest:

- Generic concepts as required to define the Gellish grammar.
- Organisms, persons and organizations.
- Geographic and marine objects.
- Occurrences, events, activities and processes, including physical, chemical, and business processes.
- Documents, information and identification.

The smallest subset is a triple, which includes a left hand object name, a relation type name and a right hand object name [20]. For example, the following statement is from a dictionary of physical objects: goods and services | is a specialization of | collection of individuals.

A thesaurus is a controlled vocabulary arranged in a known order and structured so that equivalence, homographic, hierarchical, and associative relationships among terms are displayed clearly and identified by standardized relationship indicators and allows a structural interoperability [16], [17]. *WordNet* [21] is a large lexical database of English where main parts of speech are grouped into sets of cognitive synonyms called *synsets*. Synset express distinct concepts and are interlinked by means of conceptual-semantic and lexical relations.

A search the WordNet thesauri for a word “service” returns eighteen occurrences of nouns, including those that have such meanings as "work done by one person or group that benefits another" and "a company or agency that performs a public service; subject to government regulation", and three occurrences of verbs, including those that have such meanings as “be used by; as of a utility” and “make fit for use”. By analyzing relationships of the key notion, it is possible to revise a model. In given examples it was found that *Agency* is a synonym of Company, and thus may be added to a list of entities expressed by the Organization entity.

Taxonomy and thesauri are not expressive enough to define properties, attributes and values, relations, constraints, and rules [16], [17]. Conceptual model may be complicated up-to a human conceptual level, and thus allows a semantic interoperability, but logical theory is required for a machine-processed semantic interoperability [16], [17].

An ontology is an explicit and formal specification of a conceptualization of a domain of interest [22]. An ontology defines the terms and vocabularies used to describe and represent an area of knowledge (subject matter) and meaning of those terms and vocabularies [17]. A foundational ontology is an ontology that contains objects and concepts that transcend the boundaries of a single knowledge domain [23]. A use of ontologies is natural on a modern web called web of data – the Semantic Web [24].

C. Semantic Web Models

On the Semantic Web, information is modeled primarily with a set of three complementary languages: the *Resource Description Framework* (RDF) [25], *RDF Schema* (RDFS) [26], and the *OWL* [27] Web Ontology Language [23].

Microformats [28] are a collection of individual microformats, with each one of them representing vocabularies for a specific domain and providing syntax to add semantic data into a marked-up web content [29]. *hCard* microformat is a simple, open format for publishing people, companies, organizations based on vCard RFC2426 standard [30]. *vcard* is the a root class of the hCard, and its RDF encoding was submitted [31] to World Wide Web Consortium (W3C). *hCalendar* is an open format for publishing events on the web, which is based on iCalendar RFC2445 standard [32]. *RDF Calendar* [33] specifies how to apply RDF to iCalendar data.

Friend of a Friend (FOAF) [34] is the RDF-based technology describing people, how they are linked and what they do. FOAF ontology is written in OWL. RDF vCard, RDF Calendar, and FOAF have their own namespaces, and can be used to describe such notions as Organization, Person, and Event.

The Open Geospatial Consortium (OGC) [35] handles spatial data. *CoordinateProperty* [36], *GeoOnion* [37], and *GeoInfo* [37] allow adding such geographical information as places, facts, and coordinate points to describe the Place notion. *Basic Geo* (WGS84 lat/long) Vocabulary [38] is a very basic RDF vocabulary for describing points with latitude, longitude, and altitude properties from the World Geodetic System's WGS 84 standard [39]. It uses the *Geo* microformat, which is also used by vCard.

Speaking of the Product notion, the *hProduct* microformat that is aimed to provide a structure for describing consumer goods and products is still under development. *Schema.org* provides a collection of shared vocabularies and microformats that can be understood by the major search engines: Google, Microsoft, Yandex and Yahoo! Among the others, Schema.org hosts vocabularies for such notions as Product, Offer, AggregateOffer; Organization; Person; Place, LocalBusiness, Restaurant, etc.; and Event.

The *DBpedia* [40] Knowledge Base is a community-driven extraction of structured information from Wikipedia that is made accessible on the web. At the same time it is a huge collection of Uniform Resource Identifiers (URIs) specified by the RFC 3986 [41]. *Persistent Uniform Resource Locators* (PURLs) [42] is another collection of permanent identifiers.

Foundation ontologies may contain useful sets of terms and relationships. *Dublin Core Metadata Initiative* (DCMI) [43] provides metadata for document and media publishers, but those became to be highly reusable. The Dublin Core metadata element set is standardized as ISO 15836:2009 and Z39.85-2012 [44]. Written in OWL *eClass Products and Services Ontology* [45] provides core classes and properties for eCl@ss standard [46] categorizing products and services.

Among generic multi-domain foundation ontologies, the following are well-known. *Cyc* [47] is probably the world's largest and most complete general knowledge base, containing about 239000 terms and 2093000 triples (including 19000 instances for Place, and 26000 instances for Organization), and common sense reasoning engine. *DOLCE* is the Descriptive Ontology for Linguistic and Cognitive Engineering [48]. *Freebase* [49] is community-curated database of well-known people, places, and things. *SUMO* is the Suggested Upper Merged Ontology [50], containing about 25000 terms and 80000 axioms. *BFO* is the Basic Formal Ontology, an upper level ontology that came out of a philosophical orientation, which overlaps with that of DOLCE, and SUMO [51].

Among specific foundation ontologies are the following. *OWL-Time* is time ontology presenting time concepts, written in OWL [52]. *GeoNames* [53] ontology allows adding to the web a geospatial semantic information of over 8.3 million geonames toponyms identified by URI. *CC REL* is the Creative Commons Rights Expression Language [54] that allows describing copyright licenses in RDF. *GoodRelations* [55] is probably the most powerful vocabulary for publishing all of the services and products' details. *OAI-ORE* is the Open Archives Initiative Object Reuse and Exchange [56], which provides standards for the description and exchange of aggregations of Web resources. *RDF Review Vocabulary* [57] defines a vocabulary for representing reviews and ratings, applied to products and services.

There are ontologies for specific product categories available. Some examples are: *Music Ontology* [58], *Programmes Ontology* [59], *Bibliographic Ontology* [60], *Vehicle Sales Ontology* [61], and *Consumer Electronics Ontology* [62].

Syntax and processing rules for embedding *RDF through attributes* (RDFa) [63] specifies a syntax for embedding such structured data into marked-up web documents.

D. Linked Data

The Linked Data term refers to a set of best practices for publishing and interlinking structured data on the Web [64]. Following *Web Architecture* [65] and Linked Data principles such as [66]:

1) Use URIs as names for things;
2) Use HTTP URIs so that people can look up those names;
3) When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL [67]);
4) Include links to other URIs so that they can discover more things.

In a Linked Data context, resources of different data sets ultimately connected when the RDF link connects URIs of those namespaces and thus a single global data space is formed [64]. In a result, it becomes possible to implement generic applications that operate over the complete data space [64]. Besides describing Things with RDF, it is important to make data available to an entire web space. It may be done with a help of Sitemap extension [68], or with VoID Vocabulary [64]. Provenance metadata proving a trustworthy source of data may be added by using the Dublin Core, or Creative Commons models [64]. Main models may be built using some of the above-described models, or by reusing their terms.

In selecting vocabularies for reuse the following criteria are recommended [64]:

1) Usage and uptake – is the vocabulary widely used? Will using this vocabulary make a data set more or less accessible to existing Linked Data applications?
2) Maintenance and governance – is the vocabulary actively maintained according to a clear governance process?
3) Coverage – does the vocabulary cover enough of the data set to justify adopting its terms and ontological commitments?
4) Expressivity – is the degree of expressivity in the vocabulary well appropriate to the data set and application scenario?

The following aspects are recommended to be taken into consideration when defining vocabularies [64]:

1) Utilising existing vocabularies rather than reinventing existing terms
2) Defining new terms only in a namespace under a control.
3) Using RDFS and OWL terms to relate new terms to existing ones.
4) Strictly following the Linked Data principles.
5) Providing documentation and commenting in a human-friendly manner.
6) Defining only required things within a well-defined domain to exclude an overloading of vocabularies.

A variety of search engines may help in finding terms, ontologies, their fragments or patterns. Among those are:

- *OntologyDesignPatterns.org* which is a Semantic Web portal, dedicated to ontology design patterns (ODPs) [69].
- *Dublin Core Metadata Registry* that is designed to promote the discovery and reuse of properties, classes, and other types of metadata terms [70].
- *TONES Ontology Repository* designed to be a central location for ontologies that might be of use to tools developers for testing purposes [71].
- *Swoogle* semantic web search that is able to search over 10000 ontologies [72].
- *OpenOntologyRepository* that promotes the global use and sharing of ontologies [73].

- *BioPortal* maintained by the US National Center for Biomedical Ontology that stores a large number of ontologies of medical domain.
- *eXtended Media Project* that has one goal in mind: To deliver quality content and information when it is needed [74].
- *fuzzzy* is the social bookmarking and networking site for web science academics, web professionals and web enthusiasts [75].

III. RESULTS

The GoodRelations Web Vocabulary for E-Commerce [76] was selected to be the basis data model for home service provisioning. The GoodRelations model ontology is available under the Creative Commons Attribution 3.0 license and utilises the following models, vocabularies and namespaces: RDFS, OWL, PURL, Schema.org, vCard, FOAF, DBPedia, Dublin Core, ECLASSOWL, CEO, Geo, and Yahoo.

The GoodRelations is already used by a number of e-Commerce companies and online shops, among which are Google, Yahoo!, BestBuy, Sears and Kmart. Services are listed among other specific industries, which are more tangible, such as Books, Cars, Classified ads, Concert tickets, Consumer electronics, Guided tours and outdoor events, Museum admission, Music for download, Price Comparison Engines, Real estate, Restaurants, Movies and Videos. Some of those, like Restaurants, Tours, Music, and Movies may be also a subject of home services.

A fragment of a listing in the Fig. 3 shows an example of modelling services of a local service company called IT-Parkki providing such a service as a work in the garden.

IV. CONCLUSION

An overview of important terms, vocabularies, and data models that may be utilised in data and knowledge engineering with respect to home services is presented. Authors claim that knowledge models are essential to modern web-based service systems. Such models do not restrict design of any system, but in opposite, allow a great flexibility and extensibility.

One of the most important benefits of using the knowledge models is that all the openly accessible models form along with data form a web-wide base of knowledge that is available to any system that is able to query such data and perform reasoning. Thus, protected data may remain protected, but open data becomes to be open to and discoverable by the entire web. For service providers and content suppliers such transformation of their service data means marketing and business exchange channels with an unlimited potential. A big picture of a linked data on the web may be seen from the Linking Open Data cloud diagram [77].

Practical experiments with described data models though showed a fact that a quality of data on the web is not always high. Therefore, more effort is required in maintaining of a quality of data, and provisioning both, Proof and Trust on the web. Achieving a critical mass of trusted data on the web will be beneficial to all the members of the service delivery ecosphere.

Service providers and content suppliers will get a free and low-effort means for their businesses – means that are trusted by consumers. Service and contend consumers will get a world-wide network of trusted services that may be discovered by traditional web tools (like web browsers), but also seamlessly integrated into and available through capable devices, appliances, gadgets and systems belonging to the home environment – with security and privacy ensured.

```
<div xmlns="http://www.w3.org/1999/xhtml"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:gr="http://purl.org/goodrelations/v1#"
  xmlns:foaf="http://xmlns.com/foaf/0.1/"
  xmlns:pto="http://www.productontology.org/id/">
  xmlns:vcard="http://www.w3.org/2006/vcard/ns#">
<div typeof="gr:BusinessEntity" about="#company">
    <div property="gr:legalName" content="IT-Parkki"></div>
    <div property="vcard:tel" content="3454234"></div>
    <div rel="vcard:adr">
      <div typeof="vcard:Address">
        <div property="vcard:country-name" content="Finland"></div>
        <div property="vcard:locality" content="Raahe"></div>
        <div property="vcard:postal-code" content="92100"></div>
        <div property="vcard:street-address" content="Rantakatu 5"></div>
      </div>
    </div>
<div rel="foaf:logo" resource="http://www.it-parkki.fi/sites/all/themes/zen/zen-internals/images/logo_pohjalla.png">
    </div>
    <div rel="foaf:page" resource=""></div>
  </div>
  <div typeof="gr:Offering" about="#offer1">
    <div rev="gr:offers" resource="#company"></div>
    <div property="gr:name" content="Puutarhan siivoustyöt" xml:lang="fi"></div>
    <div property="gr:description" content="Puutarhan siivoustyöt" xml:lang="fi"></div>
    <div property="gr:eligibleRegions" content="FI" datatype="xsd:string"></div>
    <div rel="foaf:depiction" resource=" "></div>
    <div rel="gr:hasPriceSpecification">
      <div typeof="gr:UnitPriceSpecification">
        <div property="gr:hasCurrency" content="EUR" datatype="xsd:string"></div>
        <div property="gr:hasCurrencyValue" content="19" datatype="xsd:float"></div>
        <div property="gr:hasUnitOfMeasurement" content="C62" datatype="xsd:string"></div>
      </div>
    </div>
    <div rel="gr:hasBusinessFunction" resource="http://purl.org/goodrelations/v1#Sell"></div>
    <div rel="gr:acceptedPaymentMethods" resource="http://purl.org/goodrelations/v1#MasterCard"></div>
    <div rel="gr:availableDeliveryMethods" resource="http://purl.org/goodrelations/v1#DeliveryModePickUp"></div>
    <div rel="foaf:page" resource="http://www.prisma.fi/tuotekuvat//originals/10.html"></div>
    <div rel="gr:includes">
      <div typeof="gr:SomeItems pto:Food" about="#product">
        <div property="gr:name" content="Puutarhan siivoustyöt" xml:lang="fi"></div>
        <div property="gr:description" content=" " xml:lang="fi"></div>
        <div rel="foaf:depiction" resource=" "></div>
        <div rel="foaf:page" resource="http://www.prisma.fi/tuotekuvat//originals/10.html"></div>
      </div>
    </div>
  </div>
```

Fig. 3. Fragment of a data model based on the GoodRelations

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