Multi-Dimensional Context-Aware Adaptation of Service Front-Ends

Project no. FP7 – ICT – 258030

Deliverable D2.3.1

CARFO Population (R1)

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## Changes

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Executive Summary

The target of this task is the population of the CARFO ontology with some of the knowledge needed to perform Advanced Adaptation Logic (AAL) for Service Front Ends (SFEs). Therefore, the main focus of this deliverable is the definition and the design of a Context Knowledge Base (CKB) assembling data for the different modules currently available in the CARFO ontology. Obviously, there is no need for building a knowledge base from scratch because there already exists a large body of work that can be reused. In the later project phase, besides new information sources, online feedback of the users, designers and developers will be collected to improve the next releases of CARFO ontology and the CKB. Building upon this knowledge base, an adaptive algorithm and advanced statistical techniques, including but not limited to, machine learning and data mining will be used to refine the defined rules.
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1 Introduction

**Ontology population** is a knowledge acquisition activity that relies on (semi-) automatic methods to transform unstructured (e.g. corpora), semi-structured (e.g. folksonomies, html pages, etc.) and structured data sources (e.g. databases, APIs, etc.) into instance data (individuals). Within the context of Serenoa project, the CARFO ontology (see D2.2.1 for the captured knowledge model) will be populated to provide contextual information which facilitates an advanced adaptation for SFEs.

The CARFO ontology is based on previous work that reports similar ontologies to gather context information and also in the theoretical models proposed by Serenoa project, namely CARF and CADS. The branches defined in the CARF model lists all concepts that are relevant for performing context-aware adaptation. As such, the branch considers the context information that is taken into account to define adaptation techniques and methods. The CADS defines dimensions in which adaptation can be considered, these dimensions have specific granularity levels that can be used to analyze and compare adaptation in different applications. The theoretical models of Serenoa, jointly with the related works analyzed, provide a basis to implement and to populate the CARFO ontology.

1.1 Objectives

The main objective of this deliverable is to describe how a knowledge base can be assembled by populating the terms described in the CARFO ontology. Obviously, there is no need for building a knowledge base from scratch, since there already exists some quite relevant work that can be reused here.

As such, the existing works were analyzed, relevant concepts were reused and the CARFO ontology is being implemented based on these works and concepts, but also contributing in the domain of context-aware adaptation mainly regarding the specific needs and requirements of Serenoa project. In the later phase of the project, the second version of this deliverable will also take into account online feedback from the users, designers and developers in order to appropriately extend the CARFO ontology and the knowledge base.

In addition, in this deliverable the first details of how to interconnect the CARFO knowledge base built upon the populated ontology with the rest of the Serenoa software modules will be delivered. It is expected that its usage for real-time gathering of adaption information will progress during the remainder of the project; in the first prototypes the use of CARFO ontology may be quite limited but as the time progresses towards the definitive versions of the system, more and more information will be extracted from it.

1.2 Audience

Partners involved in the development of the CARF (Context Aware Reference Framework), CADS (Context Aware Design Space), and CARFO ontology should refer to this document as insight into the use of these modules and their interaction (e.g. interfaces) with the CARFO knowledge base from within the Serenoa architecture. Other audience may find this document useful in order to get a short overview on how the CARFO ontology and CARFO knowledge base are used in Serenoa project to facilitate the Adaptation Server to make respective adaptations to the UIs according to the context information.

1.3 Related documents

- Deliverable D1.1.2 Requirements Analysis (R2) – describes the requirements of the project in general and discusses the gathered requirements by means of CARFO ontology and knowledge Base.
- Deliverable D1.2.1 Architectural Specifications (R1) provides useful indications about the project results that will have to be considered for the integration and use of CARFO Knowledge Base in the overall lifecycle of the Serenoa applications.
- Deliverables D2.1.1 and D2.1.2 CARF and CADS (R1 and R2) – The two releases of the CARF (Reference Framework) and CADS (Design Space) for SFEs.
- Deliverable D2.4.1 Criteria for the evaluation of CARFO ontology and Knowledge Base.
- Deliverable D4.4.1 Context of Use Runtime Infrastructure
- Deliverable D5.2.1 Applications Prototypes (R1) provides the details about the application
prototypes, thus describes the expected features whose knowledge must be stored and processed in the CARFO Knowledge Base.

1.4 Organization of this document

Chapter 2 describes the current state of CARFO ontology with its need, design and role in the overall Serenoa architecture. Currently, this ontology covers only the knowledge related to Context of Use aspects of SFEs. Chapter 3 describes briefly the process of CARFO ontology population and its interfacing with the Serenoa Runtime Engine, the tools and technologies that are used for this purpose and importantly the experimental evaluation of different queries that are performed over the knowledge stored in CARFO knowledge base. Also, it presents a subset of the queries that have been used for the evaluation of CARFO knowledge base. Chapter 4 concludes the deliverable with the clear directions for the future work. The references and acknowledgement can be found at the end of the deliverable.
2 CARFO Ontology

This chapter describes some details of the current state of CARFO ontology as it was described at its first release (R1, available in the Deliverable D2.2.1).

2.1 The need and role of CARFO Ontology in Serenoa

2.1.1 Why the CARFO Ontology is needed?

Different studies, e.g. [1] argue that an ontology-based approach is advantageous for the adaptation process, as compared to other state-of-the-art techniques, e.g. filtering. Adding further capabilities to the stack already available with XML, ontologies can be used to specify the semantics of data elements shared across systems. On one hand, the semantics defined with an XML schema are only available to the people that have specified it, while on the other hand, the semantics defined using ontologies can be determined automatically by the systems at runtime. Therefore, the use of ontologies can address the lack of data in current adaptive SFE systems. They can share and reuse data, and on the basis of the semantics formally specified in the accompanied ontologies, they can make sense of the data to exploit it for adaptation.

2.1.2 What is the role of CARFO Ontology?

In the context of Serenoa project, the CARFO ontology would be capable of capturing information about the User, the Task, the Platform, the Environment, and/or various aspects of the content (structure and presentation). This maximizes the amount of contextual information that can be used to accomplish sophisticated adaptation. Moreover, current adaptive service front-end systems rely on their own formalism and vocabulary for data representation. By the use of CARFO as a standardized ontology, the systems can share and reuse model information to solve the inherent lack of data that hinders sophisticated adaptation. It will provide formalism for the semantic annotation of the information transferred and reused across the systems. The CARFO ontology serves two main purposes in SERENOA:

The first is being the basis of a live, run-time available module, the CARFO Knowledge Base (CKB). This knowledge base will be used during execution by several of the modules in SERENOA to extract information about the adaption techniques, devices on which SERENOA may run, user information and so on. Thus, we will need not only to define CARFO as a purely a theoretical instrument, but also one that will be populated with the instances of knowledge that we may need.

In addition to this, the ontology in itself will remain as the definitive ‘dictionary’ of concept definition for SERENOA. It is expected that in the remainder of the project concepts derived from the ontology will converge with those used for defining the elements in the AAL-DL, ASFE-DL and context description language, thereby using consistent definitions of concepts and relations throughout the project. For example, when rules defined in AAL-DL use a definition of ‘event’, this should be kept consistent with that which informs the ‘events’ in the Context Manager and in the runtime for user interaction.

In all this process, we need to keep a necessary balance of complexity versus expressivity: if we possibly could fully define all concepts in adaptation and represent them in the ontology, maybe it would be excessively detailed for run-time usage and hence ultimately less useful. For that regard, many approximations and design decisions will be taken and documented in this and subsequent ontology documents.

2.2 Overview and current status of CARFO Ontology

Since the first version of the ontology was described in the deliverable D2.2.1, also known as CARFO Ontology R1, the partners continued working on providing an OWL formalization of the CARFO ontology. Under the normative namespace http://purl.org/carfo#, a snapshot of the current version of the OWL file can be lively retrieved1. The ontology has been conceived as a modular knowledge artifact, where different people could add their different modules.

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1 http://purl.org/carfo/carfo.owl
2.2.1 Context of Use module

The constituent module of CARFO ontology, the *Context of Use* module describes the vision in Serenoa project, including the *User*, the *Platform* (the *Device*) and the *Environment*. It has been designed on top of some well-known vocabularies/ontologies, such as Dublin Core, FOAF, SIOC, DOLCE, WAI or RECO, among many others.

Although this module is currently work-in-progress for archiving the second release of the ontology in six months, an updated version of all the terms is available under the normative namespace: [http://purl.org/carfo/cou#](http://purl.org/carfo/cou#) (the OWL draft could also be accessed[^2], plus some automatically generated documentation[^3]).

[^2]: [http://purl.org/carfo/cou.owl](http://purl.org/carfo/cou.owl)
3 CARFO Knowledge Base (CKB)

The CARFO Knowledge Base (CKB) is the main source of contextual information, well-structured and backed by CARFO ontology, to support the advanced adaptation of SFEs. As described in the previous chapter, currently CARFO ontology only supports the Context of Use aspects of the context related to the Platform (the Device) sub-module. The next releases of CARFO ontology will incorporate all the remaining aspects, e.g. the Environment etc.

3.1 Approach for building and populating CKB

3.1.1 What is Ontology population?

Ontology Population is the process of inserting concept instances and relation instances into an existing ontology. In a simplified view, an ontology can be thought as a set of concepts, relations among the concepts and concept instances. A concept instance is a realization of the concept in the domain, i.e. the instantiation of the concept as a phrase in a textual corpus. The process of ontology population does not change the structure of an ontology (as the concept hierarchy and non-taxonomic relations are not modified). What changes is the realizations (instances) of concepts in the domain.

3.1.2 Process of CKB Population

The approach proposed for this task, from an abstract perspective, is actually composed of a simple and linear workflow, as depicted in Abstract Process of CKB, which is a simplified form of the approach presented in [2].

1) The first step is, obviously, the identification of those suitable sources of information relevant for each module of CARFO. These information sources could be unstructured, semi-structured or structured.

2) Then the original data source would need to be processed to any custom data model using the preferred way to do it (XSLT, programmatically, etc.). Therefore those data sources exposed within any standard format, such as XML or JSON, would be much preferred than other which need an extra effort on that transformation.

3) Optionally, the data could be enriched with external sources or custom knowledge inferenc es that are not done on the original data.

4) And finally the data would be transformed into RDF individuals and serialized (preferably as RDF/XML) to be merged with other sources. At the end, all individual population efforts should be merged together on a single RDF store.

Obviously such abstract process would require to be adapted by each concrete information source. The single mandatory thing is only that all processes, at the end, should return the individuals encoded as RDF.

Additionally, the consortium has reached the agreement of using a common base URI for the individuals generated by all partners, which ideally should be: [http://puri.org/carfo/example/](http://puri.org/carfo/example/)

3.1.3 Relevant information sources

As it was already commented, there is no need for building a new knowledge base from the scratch, since there already exist some quite relevant work that can be reused here, such as:

- DDR: The Device Description Repository is a repository proposed by W3C for providing relevant capabilities of different families of devices to developers through a standard vocabulary (DDR Core Vocabulary [3]) and an API (DDR Simple API [4]). CTIC is providing publicly and freely an online version of such service implemented in the context of the MyMobileWeb project4, which follows the REST based Web Service paradigm. This service could be used for not only populating the CARFO ontology from an initial set of devices, but also for live retrieval of the capabilities of new devices

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accessing the different runtimes as well.

- **Nokia Developer**: The Nokia Developer site[^5] is providing machine-readable data about their products[^6] according to some custom ontologies developed by Nokia[^7].

  [caniuse.com[^8]]: It is an online service which provides compatibility tables for the support of HTML, CSS, SVG and more for the most popular desktop and mobile browsers. Although there is still not any public API, the Serenoa consortium has been granted with a private access to the raw data, under the CC-BY-NC license.

This initial list of data sources would be continuously updated during the following months according to the feedback from other related modules in the Serenoa platform. This would ensure that the second release of the population task would assemble a data set with sufficient quality to meet the different needs that have been detected by those modules.

### 3.2 Interfacing of CKB with Serenoa Runtime

The information (statements) stored in the CKB are actually RDF triples respecting the CARFO ontology. Therefore, the most convenient way to persist and access these statements is through an RDF store, which is an RDF database. Although less popular than relational databases, the market already offers quite many solutions, both commercial and open source. Typically such kinds of databases are accessed using SPARQL[^9] as query language and protocol. So SPARQL would be used as the primary interface for accessing the CKB by other modules in Serenoa, both at design and run time. At the same time, as soon as the requirements become defined, support for other methods, such as REST or even native APIs, could be added on top of the SPARQL interface for accessing CKB, as shown in Figure 2.

It is expected that the Adaptation Engine REST Manager and various adapters and generators in the

[^9]: [http://www.w3.org/TR/rdf-sparql-query/](http://www.w3.org/TR/rdf-sparql-query/)
adaptation pipelines will be accessing the CKB in the future. For example, information from the device description knowledge will help these modules know automatically the particulars of devices used for rendering SERENOA applications.

3.3 Experimental Evaluation of CKB

This section describes the experimental evaluation of CKB, where we performed a set of queries by interacting with CKB in order to fetch different sets of data. The CKB currently assembled can be briefly summarized with some statistics as follows:

- 5,860,540 statements (RDF triples)
- 80,952 devices models
- 9,925 browser versions (252 different browser models)
- 6,373,089 different features

This snapshot of the CKB can be queried online using a SPARQL endpoint\(^\text{10}\). Of course, dumps of the data, partial or full, can be requested by anyone who would be interested on any other particular exploitation intentions. In the following paragraphs, a subset of these queries\(^\text{11}\) is outlined.

3.3.1 Query 1

Query 1 gets the set of versions of mobile browser currently being supported by the Android platform.

```
SELECT *
FROM <http://purl.org/carfo/example>
WHERE {
    ?browser a cou:SoftwareAgentModel ;
    dct:isVersionOf <http://purl.org/carfo/example/browser/android> ;
    rdfs:label ?label ;
}
```

\(^{10}\) [http://data.ctic.es/sparql using the named graph http://purl.org/carfo/example](http://data.ctic.es/sparql using the named graph http://purl.org/carfo/example)

\(^{11}\) Prefixes declaration has been omitted to improve queries readability
3.3.2 Query 2

Query 2 gets the attributes (e.g. full name, user name, group etc.) of those people who are also professors. This information was taken from Alexandru Ioan Cuza University of IASI, Romania\(^{12}\) solely for testing purposes. However, in CKB, the real information related to the User aspect will be stored and tested in future on the same lines.

```
SELECT *
FROM <http://purl.org/carfo/example>
WHERE {
  <http://students.info.uaic.ro/people/professors> a foaf:Group ;
  foaf:member ?member .
  ?member a foaf:Person ;
  foaf:name ?fullname ;
  foaf:nick ?username .
}
```

3.3.3 Query 3

Query 3 gets a list of current browsers which support both HTML5 Web Sockets and CSS3 Border Radius.

```
SELECT *
FROM <http://purl.org/carfo/example>
WHERE {
  ?browser a cou:SoftwareAgentModel ;
  rdfs:label ?label ;
  } UNION {
  }
}
```

3.3.4 Query 4

Query 4 is performed on an FOAF knowledge base to find if two instances of foaf:Person are linked by foaf:knows relation. The information was extracted from FOAF files, collected by University of Maryland, Baltimore, USA\(^{13}\). Just like Query 1, this query was also made solely for testing purposes. The data represented contained 7118 FOAF documents collected from 2044 sites (identified by their symbolic IP address). A total of 201,612 RDF triples with provenance information were created.

```
SELECT *
FROM <http://purl.org/carfo/example>
WHERE {
  ?per1 foaf:mbox ?mailbox_1 ;
  rdf:type foaf:Person ;
  foaf:knows ?per2 ;
  foaf:mbox ?mail_box_2 ;
  rdf:type foaf:Person ;
  foaf:name ?pName_1 ;
  foaf:name ?pName_2 .
}
```

\(^{12}\) [http://students.info.uaic.ro/people](http://students.info.uaic.ro/people)

3.4 Tools and Technologies

The CARFO population task has been undertaken on a fully automatic way from the different sources of information described above (see Section 3.1.3). The toolkit covers not only the aspects related with population, but also ontology generation and the initial idea at the time of this writing about its exploitation with the interfaces for external accesses. This system has been developed in Java, the Apache Jena\textsuperscript{14} Framework as the core technology for dealing with RDF, and using SPARQL \cite{5} as the main language and protocol to cope with the data. A wider overview of the suitable technological environment that could be used to extend or improve such experiments can be found at W3C Semantic Web Standards wiki\textsuperscript{15}.

Although still not released, the current source code developed can be obtained at the subversion repository of the project at Morfeo\textsuperscript{16}.

\begin{itemize}
\item \textsuperscript{14} \url{http://incubator.apache.org/jena/}
\item \textsuperscript{15} \url{http://www.w3.org/2001/sw/wiki/Category:Tool}
\item \textsuperscript{16} \url{https://svnforge.morfeo-project.org/serenoa/trunk/carfo/api}
\end{itemize}
4 Conclusions & Future Work

This deliverable presents our approach for the complete architecture and implementation of the CARFO knowledge base, named CKB, for the population of CARFO ontology. After the first release of CARFO ontology (R1), it is still on a continuous evolution process in this phase of the project. Currently, it supports some of the knowledge related to the Context of Use aspect for the advanced adaptation of SFEs.

The CKB was not built from the scratch, but using the existing relevant sources of information. Although the set of information sources will be extended during the following months, it has already successfully populated at this stage with the tools and technologies described in the previous chapter.

Also, the first detail how the CKB can be interfaced via SPARQL with rest of the Serenoa software modules is described. It is expected that, its usage for the real-time gathering of contextual information will progress during the remainder of the project.

4.1 Future work

The future work will concentrate on the further development of the CARFO ontology and CKB. The remaining parts of the CARFO ontology will be incorporated, while the CKB will be extended with more relevant information which could meet the specific needs and requirements of different scenarios of the Serenoa project. For the second version of this deliverable, we will also take into account online feedback from the users, designers and developers in order to appropriately extend the CARFO ontology and the CKB.

Currently, only SPARQL based interface is developed to support interaction with CKB. However, in future, more interfaces (e.g. SOAP and/or REST) will be supported in order to provide flexibility and ease for other modules of Serenoa framework, i.e. Adaptation Engine REST Manager, to communicate with CKB. In addition, online feedback will be collected from users, developers and analysts in order to further improve and enhance the knowledge inference and management process.
5 References


(4) Jo Rabin, José Manuel Cantera Fonseca, Rotan Hanrahan, Ignacio Marin; *DDR Simple API*, Recommendation, W3C (2008), at [http://www.w3.org/TR/DDR-Simple-API/](http://www.w3.org/TR/DDR-Simple-API/)

Acknowledgements

- TELEFÓNICA INVESTIGACIÓN Y DESARROLLO, http://www.tid.es
- UNIVERSITE CATHOLIQUE DE LOUVAI, http://www.uclouvain.be
- ISTI, http://giove.isti.cnr.it
- GEIE ERCIM, http://www.ercim.eu
- W4, http://w4global.com
- FUNDACION CTIC http://www.fundacionctic.org
Glossary

AAL – Advanced Adaptation Logic

CADS – Context Aware Design Space

CARF – Context Aware Reference Framework

CARFO – CARF Ontology

CKB – CARFO Knowledge Base

RDF – Resource Description Framework

REST – REpresentational State Transfer

SFE – Service Front Ends

SPARQL – SPARQL Query Language for RDF

The complete list of related concepts is available at: http://serenoa.morfeo-project.org/glossary-of-terms