Enabling Access to Environmental Models, Data, and Services on the Web

– Technical Results Summary from the ENVISION Project –

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Abstract. The Environmental Services Infrastructure with Ontologies (ENVISION) project (2010-2013) provided an IT infrastructure for non ICT-skilled users for semantic discovery and adaptive chaining and composition of environmental services. This paper summarizes the core results of the project with a focus on individual components, relevant stakeholders, and overall advancements made by the project.

1 Introduction

The **ENVISION project** (http://www.envision-project.eu/) ran from 2010 to 2012 and had as its main goal the development of an IT infrastructure supporting users with limited ICT skills in decision making processes involving environmental services. The project addressed emerging topics related to environmental services, ranging from semantic discovery, chaining and execution of environmental services, to migration of environmental models to be provided as models-as-a-service (MaaS) [1], to use of data streaming information for harvesting information for dynamic building of ontologies.

The ENVISION project combined and extended tools and components with functionality for easier use by non ICT-skilled users and with increased semantic technology support in an incremental development approach. Figure 1 shows the main focus areas and contributions in ENVISION. Each area is accessible to the one above.

The *ENVISION Execution infrastructure* provides the basis for resource discovery and composition. Semantic interoperability is facilitated by the *ENVISION Ontology infrastructure*, which contains ontologies, resource descriptions, and supporting tools. Both mentioned components provide input to the *ENVISION Portal and Development* tools. This area is also responsible for providing client components for interfacing with the ontology and execution infrastructure. All areas in conjunction are applied to the *ENVISION Communities*. These communities require application specific decision support. Customised portals are developed for three pilot cases (landslide, oil spills at sea, and flooding), which serve as a proof of concept for the project.

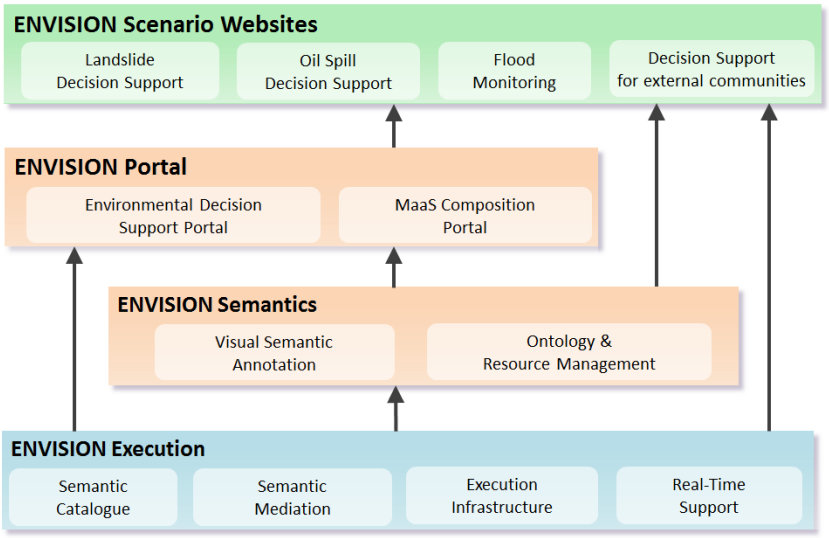

Figure 1. ENVISON focus and contribution areas

In the following we give an overview of specific areas of contributions related to the aforementioned architecture. For each artefact we provide a brief description, discuss relevant stakeholders, discuss advancements in the project, and summarize the core S&T results.

2 ENVISION Pilots – Scenarios Websites

Landslide Scenario Website

A scenario website[1] has been set up to present the results of a simulation predicting the potential location of landslide in the Mamelles area. In this website, users can initiate the execution of a model calculating risks for each area a landslide occurs.

Stakeholders: The Landslide website is dedicated to citizens and also to public authorities who may use it as a help to know if they need to take specific measure after some meteorological event.

Advances in the project: The components of the landslide model come from a desktop application, ENVISION had given the opportunity to make them available on the Web using OGC standards.[2]

Core S&T results: The project delivered a new way for non ICT-skilled domain experts to easily create websites for large diffusion of results of their studies. It also

[1] The Landslide Scenario Website can be viewed on the BRGM ENVISION portal at: http://envision-portal.brgm-rec.fr/en/web/rd23-landslides/mamelles-road.

[2] http://www.opengeospatial.org/standards/is

delivered a tool to easily combine atomic process to create new workflow for the computation of environmental models. The project also delivered to the landslide community a new technology to share easily the models they create. With this technology, the public authorities can also access in a faster way the results of simulation without the need of a landslide expert.

Oil Spill Scenario Website

For the Oil Spill pilot case, a scenario website was established.[3] At this website, users may define an oil spill scenario in the North Sea region, run a simulation that predicts the fate and effects of the spill, and then visualize the results as animated layers on a map.

Stakeholders: The Oil Spill Scenario Website is oriented towards researchers (in the oil spill domain, or in related domains), private companies and public agencies involved in oil spill contingency planning, and also the general public.

Advances in the project: Traditionally, oil drift models are embedded in applications and can only be accessed via that application's user interface. In ENVISION, SINTEF's oil drift model OSCAR[4] has been made accessible via a standard web interface.

Core S&T results: The project delivered a new and user-friendly approach for creating a domain-oriented website for the oil spill community. The web site enables invoking and running composite model services, and also visualizing and analyzing simulation results. The web site may easily be adapted or extended to cover other geographical regions.

Flood Monitoring Scenario Website

For Flood Monitoring pilot case a website scenario was setup on an instance of the ENVISION platform[5]. The scenario website allows the users to observe current (real-time) and historical water levels and water flows values on Danube River and its main tributaries in the area controlled by the Iron Gates hydro-power plant (Romania/Serbia). In case of high-waters events, a model was implemented for water evacuation through dam gates in order to reduce or avoid the flood risk in this area.

Stakeholders: The scenario website provides valuable information for hydro-power plant operators for both Romanian and Serbian sides, for the decision makers in the public institutions (i.e. hydrologic services, waters administration, emergency situations) and also for the general public.

Advances in the project: Currently, such floods monitoring applications are internally handled by each interested organisation, using custom desktop or Web applications which hinder data sharing and modelling results exchange.

Core S&T results: The pilot case allows hydrologists and hydro-power plant operators to easily create websites for monitoring different interest areas were sensors are

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3 The website can be accessed via envision.envip.eu.

4 http://www.sintef.no/Materialer-og-kjemi/Marin-miljoteknologi/Miljomodellering/Modellverktoy/OSCAR-Oil-Spill-Contingency-And-Response/Model-Description/.

5 http://envision.c-s.ro.

available. Existing data and processing services can be combined to provide new add-value services.

Further details about the pilot cases can be found in [2,3].

2 ENVISION Portal

Environmental Decision Support Portal

The Environmental Decision Support Portal plays a major role in the infrastructure, allowing non ICT-skilled users to manage by themselves the whole workflow of search, creation, diffusion of environmental services.

Stakeholders: The potential users are domain experts, who are using environmental models or creating new ones and want to share their results; end users, citizens, public organizations, who want to consult the results of environmental models on a certain thematic on a specific area.

Advances in the project: The project has made available some components pluggable in a web portal such as Liferay.[6] These components allow a non ICT-skilled user to perform the tasks of the ENVISION workflow (semantic discovery, annotation, publication in the catalogue, composition of environmental services, visualization). In these pluggable components, some of them are dedicated for the creation of Scenario Web Site by the domain expert. These components are used by the domain experts to allow the visualization of the results of the models they have created. These components allow easily and without any IT knowledge to add in a web site a map for visualization of data coming from OGC services (raster data from a WMS,[7] vector data from a WFS,[8] data series from a SOS[9]); they also allow to visualize the data in a chart and to view the evolution of a phenomena in the map during a given time. All these tools are easily configurable directly in the web site in a visual way and a role based security can be activated for each web site, page or component to restrict the access to non-authorized people. The final user can then visualize the results of the environmental models on a map or on a chart in the context defined by the domain expert.

Core S&T results: The project delivered (a) a new approach for the creation of thematic web sites for the diffusion of environmental data generate by the execution of chained models; (b) an open source implementation allowing a non ICT-skilled user to easily create web site containing tools for the visualization of data coming from OGC services and for results of the execution of environmental models.

Further details about the ENVISION portal can be found in [4].

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6 https://www.liferay.com/

7 http://www.opengeospatial.org/standards/wms

8 http://www.opengeospatial.org/standards/wfs

9 http://www.opengeospatial.org/standards/sos

Composition of OGC Services

In order to create the applications of the ENVISION use cases (land slide, oil spill, cod effects and flood monitoring), there is a need to call several OGC services and chain them together. This is done with a so-called service composition. The OGC services used in the land slide scenario: an SOS service to retrieve the amount of precipitation, a WCS service to get a digital elevation model of the Guadeloupe island (the area of interest for the land slide scenario), a WPS to calculate a hydrological model, and finally a WPS to calculate the probabilities of a landslide. The OGC services used in the oil spill scenario: A WFS to retrieve coastline information, a WCS to retrieve sea depth information, a WPS to retrieve weather information, and finally a WPS to predict how the oil spill spreads over time.

The project has developed a new approach for composing OGC services by using a graphical modeling language to model the control and data flow. It is based on current standards and tailored for OGC services. Technical details are automatically registered and hidden from the user to lower the complexity level in using the tool.

Stakeholders: The development of a composition approach is directed to developers of new services that want a fast and efficient support for putting together environmental services without the need to code or dig into technical details. The approach also has the potential to reach non-ICT skilled domain experts with some future development and maturity of the given platform in the feature.

Advances in the project: The project provided new insights in the composition of OGC services. The approach is tailored for the specifics of OGC services, where other approaches only address Web service composition in general. We have identified the typical challenges when mediating between OGC services so to enable that they can be chained together. While mediation between Web services in general is a very complicated matter, it turns out that many typical scenarios of mediating between OGC services can be handled in a semi-automated and simple manner with the gained knowledge from the ENVISION project.

When the project started there was no tool available to search, register and integrate OGC services over the Web. This is now achieved by the ENVISION platform.

Core S&T results: The project delivered a new approach for (a) composition of OGC-based service, (b) a composition platform integrated with discovery and registration capabilities (c) a composition platform integrated with a mediation framework described below, and (d) fully automated generation of WSDL and BPEL for the deployment and execution of OGC service compositions.

Further details about the composition approach can be found in [5].

3 ENVISION Semantics

Semantic Annotation

Ontologies and ontology management play an important role in the ENVISION infrastructure because in order to enable efficient browse and search through resources and efficient composition and execution of Web services, the resources

need to be semantically annotated. Generally, resources such as Web services can be annotated in different ways. In ENVISION, semantic annotation is defined as a set of interlinked domain-ontology elements associated with the resource being annotated.

Stakeholders: The potential users are domain experts, which are dealing with semantic annotations of different data sources, possibly cross-lingual.

Advances in the project: The technology in ENVISION, which enables visual management (creation and editing) of semantic annotations and ontology querying, was implemented in a software component named Visual OntoBridge. Visual OntoBridge integrates several existing scientific methods but also implements several novel approaches for cross language annotations. Visual OntoBridge is implemented as a *portlet* (a pluggable user interface software component) which can be plugged into a portal (ENVISION employs the Liferay Portal).

Core S&T results: Core results are within the areas of domain ontology querying, cross-language domain ontology querying, and visual editing of semantic annotations, as explained below.

Domain ontology querying is implemented by employing text mining techniques, the PageRank algorithm and general Web search. The user can enter a Google-like query and receives a list of ontology concepts which are sorted from the most to the least relevant. To achieve this, Visual OntoBridge implements a number of text mining methods and a variant of the PageRank algorithm which exploits the ontology structure enriched with documents obtained from the web.

Cross-language domain ontology querying*:* The core idea of the machine-aided annotation in ENVISION is based on term matching through groundings obtained by a Web search engine. The user can enter a query in any of the supported languages and receive a list of relevant results (which may be slightly different from language to language and in different order).

Visual editing of semantic annotations: Establishing semantic annotations of resource (such as Web services) using big and complex domain ontologies is not an easy task, especially for users which are not familiar with underlying technologies. For that reason, Visual OntoBridge provides technologies which make the creation of semantic annotations easy and visually appealing. Visual OntoBridge implements an application independent annotation editor which employs graph representations of ontologies and resources to simplify the annotation. Thus, the act of creating a semantic annotation is represented by establishing connections between graph nodes representing ontology concept instances and the resource, also shown as a graph.

Visual OntoBridge enables visual annotation editing which does not require specific skills or knowledge. The user is only required to be familiar with the topic of the domain ontology and its relation to the resource (web service). The process of creating an annotation is represented through graph editing actions (adding/removing edges by connecting/disconnecting nodes representing the resource and concept instances).

Further details about the annotation approach can be found in [6,7].

Ontology Management for the Semantic Annotation of Environmental Models

ENVISION provided an online platform to support the migration of environmental models to be provided as models as a service (MaaS). The development of ontologies for semantic annotation of Web services required a proper ontology engineering methodology and tools which allow ontology maintenance. These annotations are relevant for the semantic discovery of resources, the mediation between services, and the execution of the environmental workflows.

Stakeholders: The ontology management strategy presented in ENVISION addresses scientists who are not ontology experts. They are interested in sharing their environmental models as service compositions with the scientific community in order to get feedback and to explore the possibilities of reusability of the model in other scenarios.

Advances in the project: ENVISION extended and improved previous work on semantic annotations for OGC services with a methodology for adding semantic annotations to the OGC service specifications (SOS, WFS, WPS, WCS, and WMS). The methodology also covers the annotation of WSDL services. Additionally, ENVISION provided tools for the online management of resources as Web services (both standard W3C services as well OGC-compliant Web services), WSML ontologies, and BPEL composition drafts.

Core S&T results: Some of the main components that the project delivered for the management of semantic annotations of environmental models include: *Resource management* (the Resource Portlet manages the access to all resources required to perform the individual activities of the ENVISION platform); *Service Model Translator (SMT)* (The SMT translates a capabilities document provided by a Web service into RDF-based and WSDL service descriptions. The supported specifications are: SOS, WFS, WPS, WCS, and WMS. SMT creates both description representations for each provided feature type or observed property of the corresponding Web service); and *Data Models, Service Models and Domain Ontologies*.

Further details about the annotation approach can be found in [7].

4 ENVISION Execution

Semantic Discovery

Semantic discovery is a key component of ENVISION infrastructure enabling users to find relevant OGC resources and services. It provides an intelligent and precise discovery mechanism as part of what we call the Semantic Catalogue. The Semantic Catalogue provides a semantic extension to standard OGC discovery of services, which uses semantic annotations and reasoning over service descriptions formalized by means of logics.

Stakeholders: The Semantic Discovery functionality can be used by a wide range of users with different technical skills. By using the Semantic Discovery Portlet, non ICT-skilled users can easily search for environmental services registered in the catalogue. Queries can be easily specified either as keywords or using the Visual

OntoBridge. More technical users i.e. developers can use the results of querying the Semantic Catalogue to create new services by using the composition component.

Advances in the project: In ENVISION we advanced the state of the art with respect to discovery of environmental services in several aspects. To implement our solution we used an open source catalogue (i.e. GeoNetwork) and extended it to support semantic queries. The Frozen Facts approach for query containment, was used for semantic discovery. Developed as part of the SWING project, the Frozen Facts approach for query containment, part of the IRIS reasoner has been extended and optimized. We have added support for negation, built in predicates, etc.

Core S&T results: The project delivered two main results: (1) a robust service discovery mechanism with full support for semantic queries based on WSML goals and query containment algorithms and (2) a well integrated solution of an open source OGC catalogue (i.e. GeoNetwork[10]) with the semantic service discovery mechanism mentioned before. We have also provided a user interface for the discovery inside the ENVISION platform, wrapped in a portlet and provided the necessary interface to connect the portlet with both the Resource Module and the WSML goal editor in order to fully integrate the functionality provided by the ENVISION platform.

Further details about the discovery approach can be found in [8].

Mediation Framework

The Mediation Framework enables the rapid prototyping of data mediation algorithms. Developers can thus quickly build, deploy and evaluate mediation services on specific or public data sets. It also permits to communicate data models, and to evaluate the effectiveness of existing solutions. The resulting mediation services can be easily shared with the data mediation community – if needed, but can also be integrated into existing software architectures, as done in the ENVISION project.

Stakeholders: This framework targets users who face data mediation issues (e.g. software engineers, etc.), typical in service compositions, document exchanges, interoperability, etc. It lightens the development of algorithms by providing basic mediation features as a library, and supports the evaluation of the resulting mediation algorithms by automating comparisons with alternative solutions on predefined data sets.

Advances in the project: Data mediation is a complex issue, for which there is unfortunately no "silver bullet". Recent approaches strive for the development of generic algorithms able to solve any mediation problem. This framework concretizes an alternative approach focusing on the rapid prototyping of application-specific algorithms, where one accepts to lower algorithms reusability in order to provide higher effectiveness by making the most of application specificities.

Core S&T results: The project delivered two main results: a new approach for rapid prototyping of data mediation and the supported open-source implementation available on Github.

Further details about the mediation approach can be found in [5].

[10] http://geonetwork-opensource.org/

Stream Mining of Environmental Data

In the environmental domain Stream Mining techniques are still not widely present. With the developed EnStreaM component in ENVISION we have shown the usability and applicability of Stream Mining in the environmental domain. One of the environmental data features is that for complete analysis of environmental phenomena, one has to combine stream data on one hand and "static" data on the other hand. In the development of stream mining component (EnStreaM) this fact is introduced and resolved in a way, that the component is able to "listen" and analyze the data streams as well as offering the possibility of import the history data about the observed environmental phenomena in the conventional data format. The developed component enables stream mining methods and a prototype system for handling semantic data streams and stream ontologies including the information from the sensor data streams.

Stakeholders: Potential users of stream mining in environmental data are domain experts, specialized for observed environmental phenomena. Part of EnStreaM component is also user friendly graphical interface, which offers complex visualization of stream and historical data analysis, which is intuitive enough also for non-ICT skilled users. However, the configuration process demands some basic understanding regarding semantic annotations and its usage.

Advances in the project: The EnStreaM component is designed in a way that supports import of various data (sensor data and static-metadata about selected environmental phenomena) and provides wide range of functionalities: from simple to complex browsing of sensor data, discovery and validation of expert rules (which could be used for alarm triggering), anomaly detection in almost real-time (which enables detection of broken sensor) and prediction of selected phenomena in various time spans. Visualization of selected sensor on the map and ability to selected sensors from the map itself enable users to combine data from appropriate geographical areas in very straightforward way.

Core S&T results: Developed functionalities enable support for: Data stream summarization in a configurable manner; Discovery of anomalies in the data stream; Prediction of events; The expert domain user to semi-automatically generate, validate and export rule for selected events in environment, measured by sensors; Rule export in DataLog, JSoN and RuleML format.

Further details about the mediation approach can be found in [9].

Notification Infrastructure based on Semantic Event Processing

In domain applications dealing with environmental change, like flood monitoring, it is normally required to exchange geospatial information about relevant occurrences as they are detected. Different information communities may use diverse models to represent changes in our environment, thus causing interoperability problems when the information they produce is shared. In ENVISION, we proposed a layered ontology model based on event processing to detect and classify occurrences derived from sensor observations, and described them using domain knowledge. Such model is integrated into our Notification Infrastructure which offers tools for event subscription and notification by email.

Stakeholders: There are two types of users for the Notification Infrastructure. Domain experts are needed to register semantically annotated event definitions that are essential for the semi-automatic classification of occurrences. On the other hand, the event subscription interface is designed for non ICT-skilled users, but can be used by anyone.

Advances in the project: The application of Semantic Event Processing to geospatial information is a relatively new field. In the last years, there has been some research work mostly on event-based ontologies and detection of occurrences in time series of observations, but not focusing too much on the interoperability problems that different perspectives and application purposes can cause. Our solution is designed to accept representations of events from multiple domains involved in environmental monitoring. Additionally, we use a semantic-based notification system to avoid that users have to deal with technical event definitions.

Core S&T results: The main components that are included in the Notification Infrastructure based on Semantic Event Processing are: Event Processing Service (EPS); Event-Observation ontology; Semantic Notification Broker (SNB); Subscription Portlet**.**

Further details about the mediation approach can be found in [10].

Stream Reasoning on Environmental Data

Environmental data is becoming more and more available as streams. To be able to derive new knowledge based on such data, new reasoning techniques are needed. We have developed Streaming IRIS, a Datalog stream based reasoned, that support reasoning with rules on streams of Environmental data.

Stakeholders: Stream reasoning is mostly intended to be used by technical users with a background in knowledge representation and reasoning.

Advances in the project: Streaming IRIS fills a gap that emerged due to the increasing amount of available live environmental data. Various system are available which are able to process the data in terms pattern matching and filtering as well as light weight reasoning, e.g. Complex Event Processing (CEP). But these systems lack in extracting implicit knowledge of these data streams. While providing the full reasoning capabilities of Datalog, Streaming IRIS extends Integrated Rule Inference System (IRIS) with the ability to work in a streaming environment. Complex reasoning tasks can be performed in a continuous way, by registering queries into the system, taking the dynamic streamed data and eventual static background knowledge into account.

Core S&T results: There are several results delivered as part of the work performed on stream reasoning: *Streaming IRIS*, a Datalog stream based reasoned build on top of the Datalog IRIS reasoner; *WSML2Reasoner extensions* (support to integrate the Streaming IRIS); *Sparkwave* (a system that supports schema-enhanced pattern matching over RDF data streams).

Execution of Environmental Models as WS-BPEL Processes

In order to facilitate the development, delivery, and reuse of environmental software models service orientation has been recently pushed forward by several important initiatives, such as INSPIRE, GMES, and SEIS, and international standardization bodies, such as OGC. In the light of those efforts, both geospatial data and geo-

processing units are exposed as Web services, which can be used as building blocks for the composition of environmental models, in the form of WS-BPEL processes. However, several challenges arise upon this paradigm shift. Efficient execution and monitoring of long-running environmental processes that consume and produce large volumes of data, in the presence of multiple concurrent process instances are among the prominent issues that one should effectively deal with.

Stakeholders: During the course of the project, ENVISION has particularly targeted companies and organizations that require an efficient and relatively low-cost setting to execute environmental WS-BPEL processes, which are long-running, produce and/or consume voluminous data, and are concurrently accessed by multiple users. IT entrepreneurs who implement and deliver resource-demanding environmental models as WS-BPEL processes, but cannot afford expensive servers to host a cluster of BPEL engines, are first-class citizens of the target group of the ENVISION Adaptive Execution Infrastructure.

Advances in the project: The ENVISION Adaptive Execution Infrastructure departs from the various existing solutions for WS-BPEL process execution in numerous ways. More specifically, the work conducted in this context revolved around the implementation of the following two innovative features: data-driven adaptation and decentralized execution.

Core S&T results: Through its three-year course, the ENVISION project delivered numerous technologies related to the execution of WS-BPEL processes. The most prominent ones include: A decentralized WS-BPEL engine; A Semantic Context Space (SCS) engine, a Process Optimizer, and a Semantic data mediation engine.

Further details about the execution approach can be found in [11].

5 Summary

ENVISION targeted the implementation of Web-enabled pluggable user interface components for the creation of domain-specific Web sites for the environmental modelling community. This included tools and approaches for the discovery, semantic annotation, and adaptive composition of workflows representing environmental process models. With these new mechanisms in place, ENVISION has made a number of advances beyond state of the art approaches as outlined in this paper, opening new paths for better access to environmental models, data, and service on the Web.

The ENVISION platform, together with its components has been made available under open source licenses.[11] A set of demonstrators showing the various aspects of the platform presented in this paper have been made available online.[12] Extensive materials produced by the project, including technical reports, scientific publications,

[11] The ENVISION open source project is available at https://kenai.com/projects/envision/pages/Home.

[12] Demonstrator can be accessed via http://www.envision-project.eu/resources/screencasts-demonstrators/.

ontologies, annotate services, user stories, installation guides, results of end-user workshops are available on the project website.[13]

Acknowledgment. This work was funded by the EU project ENVISION (FP7-249120).

References

1. D. Roman, S. Schade, A. J. Berre, N. R. Bodsberg, J. Langlois. *Model as a Service (MaaS)*. Position Paper at Grid Technologies for Geospatial Applications Workshop, 2009. Paper available via http://ifgi.uni-muenster.de/archives/agile/submissions/AGILE-GridWorkshop-Roman.pdf.
2. ENVISION Deliverable D1.6. *Report presenting validation of ENVISION results*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2013/01/D1.6v1.0.pdf.
3. ENVISION Deliverable D1.8. *Development of an operational system by applying the ENVISION results to the pilot cases*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2012/10/D1-8_v1-0.pdf.
4. ENVISION Deliverable D2.4. *Environmental Semantic Web Portal Version 3 – Final development and user guide*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2012/12/D2.4-v1.pdf.
5. ENVISION Deliverable D3.4. *MaaS Composition Portal Version 3 – Final development and user guide*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2012/12/D3.4-Maas-CompositionPortal.pdf.
6. ENVISION Deliverable 4.4. Cross language and cross domain annotation software. Available at http://www.envision-project.eu/wp-content/uploads/2012/02/ENVISION_D4.4_FINAL_for_pdf.pdf.
7. ENVISION Deliverable 4.6. *Annotation management report and final components*. Available at http://www.envision-project.eu/wp-content/uploads/2010/01/D4.6_v10.pdf.
8. ENVISION Deliverable D5.4. *Integration of the open source catalogue with the semantic discovery engine – Version 2*, 2012, Available at http://www.envision-project.eu/wp-content/uploads/2012/05/D5.4-Integration-of-the-open-source-catalogue-with-the-semantic-discovery-engine-Version-II-_M24_v2.0.pdf.
9. ENVISION Deliverable D4.5. *Semantic data streams and stream ontologies software*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2012/11/D4-5_v1-01.pdf.
10. ENVISION Deliverable D4.7. *Event processing of observation data*, 2012. Available at http://www.envision-project.eu/wp-content/uploads/2013/02/D4.7-1.0.pdf.
11. ENVISION Deliverable D6.4. *ENVISION Adaptive Execution Infrastructure Version 3 – Final prototype, user guide and evaluation*, 2013. Available at http://www.envision-project.eu/wp-content/uploads/2012/12/D6.4_v1.0.pdf.

[13] Accessible via http://www.envision-project.eu/resources/.