

Exploring a novel service deployment framework, PIASK, through the design and implementation of an e-commerce function for a rural community

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Abstract—ICT solutions deployed in rural, marginalized areas seldom encapsulate the cultural and contextual considerations needed to ensure communities' buy-in, ownership, and sustainability. Today, knowledge has become a major commercial commodity, and access to knowledge networks has paramount financial benefits for communities, and can help bootstrap and leapfrog community development. We have developed an architecture, called PIASK, for the provision of semantically rich, multimedia and multi-modal access, ontology-based services for communities. In this paper the adequacy of this service framework is explored through the initial design and the development of an e-commerce function. We envisage that this culturally sensitive e-commerce solution will activate local entrepreneurship and provide a rich end-user experience.

Index Terms— M-Commerce, Web and Application Servers, Knowledge Networking, Semantic Web, RDF/XML, Rural ICT

I. INTRODUCTION

The information revolution, driven by the advancements in technology, has introduced new information usage paradigms and challenged the traditional notions of knowledge production and consumption [1]. The key component of this revolution has been the Internet, which facilitates a distributed hosting of heterogeneous information which is made accessible to a multiplicity of devices through various protocols and standards. Inherent in Tim Berners Lee's vision of the Internet is the notion of a ubiquitous knowledge repository that encapsulates not only the structure of the data but also the associated semantics [7]. Numerous advancements in the field of Artificial Intelligence and Computer Science have brought the vision of the semantic web into reality through Knowledge Representation (KR) languages (e.g., RDF, OWL, DAML + OIL), knowledge processing heuristics and knowledge modeling tools and applications.

Juxtaposed to these advancements in Information and Communication Technologies (ICT), is a growing rift and line of demarcation between those who have access to

information and communication technologies and those who do not [2]. This rift in societies, usually referred to as the digital divide, leads to information marginalization and participatory exclusion of individuals and societies from the Internet driven knowledge economy. This marginalization has direct ramifications to the societal-well being of communities due to the direct correlation between access to information and the corresponding access to economic opportunities, a concern raised by the United Nation's Administrative Committee on Coordination [3].

ICT and connectivity to the Internet have the potential to leap-frog development within a community. The advantages and possibilities that are opened up to communities by the connectivity to the Internet include empowered decision making, participation in the knowledge economy, and collaborative knowledge production. These benefits are realizable through the meaningful interaction of the users with information repositories to create knowledge that is then integrated into their daily activities. The full effectiveness of the Internet is realized through the implementation and provisioning of semantic capabilities in information processing i.e. the capability of information to be meaningful, both to the end users and to the information processing agents, through the encapsulation and integration of local knowledge (usually referred to as Indigenous Knowledge (IK)) and through the implementation of services that provide direct benefits to the communities in which they are deployed [4].

One such service that has a direct benefit to communities is e-commerce for the stimulation of local entrepreneurship and economic activity. This paper discusses the development and implementation of a semantically rich, contextually relevant e-commerce environment that encapsulates local knowledge based on PIASK, a knowledge-based service implementation framework developed by the authors and presented in [4]. The next section provides a high level overview of the 5 layers of the PIASK framework, indicating the relevance of this model for the provisioning of an architecture that meets the requirements of web services deployed in marginalized areas. The third section discusses the role of indigenous knowledge within the context of the knowledge economy, and introduces the various ontologies that form the basis of

the knowledge platform envisaged for deployment in a rural, marginalized area. The e-commerce ontology, ontecom, is one of the ontologies that form the Knowledge Base (KB) layer in the platform, and provides the underlying knowledge base for the e-commerce services and applications. Section IV provides the details of the e-commerce ontology, and the associated applications.

II. PIASK OVERVIEW

PIASK is a layered architectural model for knowledge systems that allow multi-modal access to multimedia data (Fig. 1) [4]. An important contribution to the development of this model comes from social constructivism which views the synthesis and utilization of knowledge in the context of social relations between members of a community [5].

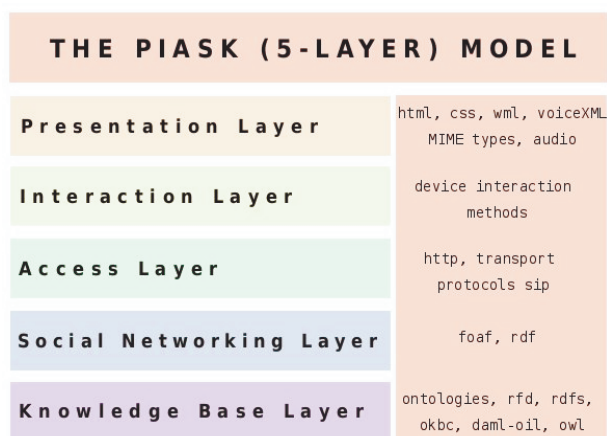


Figure 1. PIASK Architectural Model

The lowest layer of PIASK is the Knowledge Base layer, which handles the storage and representation of knowledge within the system. This layer codifies knowledge using standard KR languages to facilitate ease of integration of any ontology into the system and to enable sharing of local knowledge with other systems. The Open Knowledge Base Connectivity (OKBC) interface is used to connect to other KR systems and legacy knowledge systems.

The second layer in the model is the social networking layer, which facilitates the relational interaction among the various users of the knowledge coded in the KB layer. This layer handles issues related to trust, group membership and identities on the network.

The top three layers of the model are the access layer, the interaction layer, and the presentation layer. These layers handle the heterogeneity of knowledge and the multiplicity of end-user devices on the system. They take into consideration the transport protocols used to access the knowledge bases, the various interaction methods with the devices, and the various display and presentation capabilities of devices respectively.

III. KNOWLEDGE NETWORKS

Knowledge has always played a crucial role in the economy, in the form of skills and best practices for various

industries. In an agricultural economy for example, knowledge about farming seasons, and about the best methods of farming, supports and facilitates effective usage of the primary resource, land. In the knowledge economy however, knowledge takes a more central role where “the principal component of value creation, productivity and economic growth is knowledge” [6].

Implementing knowledge portals for marginalized communities allows for the codification of IK which is then usable within the community for facilitating economic activities. It also activates the users within the knowledge society, by allowing for meaningful exchanges of knowledge with other communities of practice. Naturally the design and implementation of these portals has to take into consideration the specific anthropocentric requirements and profiles of the targeted communities in order to reach maximum usage effectiveness.

The pervasiveness of knowledge in the economy has been heightened by the ability to process and distribute information effectively via the Internet. The limitation of this infrastructure, the Internet, was the near impossibility for the network nodes to process the information at a semantic level. This limitation has ramifications in web applications and services. For example, search engines would not return results for synonymous terms to the key search term, unless an explicit lexical mapping had been done; e-commerce applications do not support browsing features where related products would be suggested, unless they are hard-coded into the software logic. The Internet is envisioned as a distributed and ubiquitous knowledge that is not encapsulated in the domain expert applications but rather ingrained in the machine-processable meta-data [7] via suitable ontologies. An ontology is a formalized body of knowledge about a specific domain [8], capturing the domain vocabulary and the relationships between the different domain concepts [9].

The knowledge platform (Fig. 2) envisaged for deployment in Dwesa, a rural marginalized region in the Eastern Cape province of South Africa, comprises four core ontologies at the KB layer:

1) *Health-Ontology*: Knowledge about the traditional medicines and health considerations is encapsulated within societies as tacit knowledge. This ontology codifies the indigenous health practices and knowledge in a manner that allows for ease of use of the knowledge as well as an easy integration with other external health ontologies.

2) *Commerce Ontology*: This ontology defines the body of knowledge surrounding commerce. It defines the classes and the associated properties of products, the different roles of users of the e-commerce platform and the relations between the different entities.

3) *Xhosa-Ontology*: This ontology embodies the knowledge about the culture and the traditions of the community in Dwesa.

4) *Agri-Ontology*: Rural and marginalized communities possess practical knowledge in the area of agriculture because the majority of these communities rely on subsistence farming for a living. The agri-ontology

embodies the knowledge in the agricultural sector of the community.

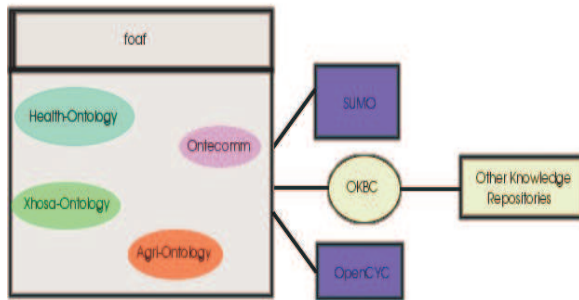


Figure 2. Envisaged Knowledge Platform

Additional knowledge is encapsulated and accessible in the platform through the Suggested Upper Merged Ontology (SUMO) ontology, the OpenCYC ontology, and other knowledge bases that are connected via the Open Knowledge Base Connectivity (OKBC) interface. At the social networking layer of the model, the Friend Of A Friend (FOAF) specification provides the ability to model the relational interactions among the users of the platform.

IV. ONTOLOGY-BASED E-COMMERCE ENVIRONMENT

This section details an implementation of an e-commerce function within the PIASK architecture.

A. The Implementation Context

The implementation context of this e-commerce service is Dwesa. Dwesa has economic potential through the presence of arts and crafts entrepreneurs, and a nature reserve. Deploying an e-commerce platform in this area should activate the community to participate in the economic activity, and at the same time allowing access to wider markets. Dwesa is the site of a project undertaken between the Universities of Fort Hare and Rhodes, to develop and field-test a prototype of a simple, cost-effective and robust, integrated e-commerce/ telecommunications platform for deployment in marginalized areas [10]. The currently deployed infrastructure consists of:

1. A WiMAX local loop that connects four points of presence in Dwesa
2. A Very Small Aperture Terminal (VSAT) satellite back-haul connection to the Internet.
3. A webserver, Apache, hosting local knowledge repositories.
4. An Asterisk-based VOIP server that handles voice communication [11].
5. Computer clusters that are set up to allow Internet usage and accessibility.

The e-commerce platform features a web-browser front

end, accessible to the customers, and an interface for the arts and crafts entrepreneurs, and services and goods sellers (shopkeepers). The level of use of computers and computing facilities in the region is essentially zero, while cellphones on the other hand are not uncommon (A 2006 report released by the GSM Association pegs the sales of mobile phones in developing countries up to 800 million [12]). To leverage this proliferation of cellphones in rural communities, a client was developed to allow shopkeepers to update their virtual shops via cellphones.

B. The ontology

The commerce ontology, *ontecom*, currently defines a minimal set of slots and facets (classes and properties) necessary for a functional implementation of an e-commerce portal (Fig. 3). The *owl:Thing* class is the default parent of the *ontecom:category* class, *ontecom:item* class, *ontecom:person* class and the *ontecom:region* class. The *ontecom:item* class is further sub-classed into:

1. *ontecom:event*, events which customers can attend. For example, music and dance shows.
2. *ontecom:product*, items and products for sale. These include arts and crafts, and cultural artifacts.
3. *ontecom:service*, services that are provided for the customers. Accommodation services and leisure services are examples of instances of this class.

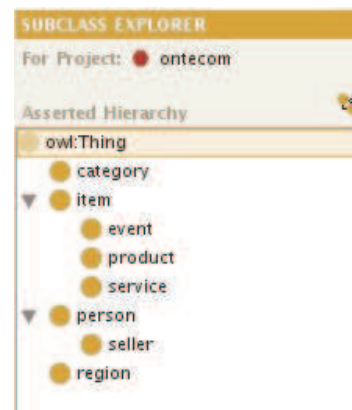


Figure 3. E-commerce Ontology Class browser

The properties defined in the e-commerce ontology are listed in Table 1.

The domain specifies the objects which map the property to the range. For example, the *ontecom:person* class is mapped to a string that specifies the name of the person by the property *hasName*. As an N-Triples statement this

would be $\langle domain \rangle \langle property \rangle \langle range \rangle$. The *hasCategoryItems* and *inCategory* properties are inversely related, so are the *hasSeller* and *sells* properties. The *knows* property which maps one *ontecom:person* instance to another is a symmetric property in this ontology.

PROPERTY	DOMAIN	RANGE
hasCategoryItems	#category	#item
hasComment	#item	string
hasContactNumber	#person	string
hasDescription	#item	string
hasImage	#product #person	string
hasName	#region #person #item	string
hasPrice	#product #service	float
hasQuantity	#product	int
hasSeller	#product #service	#seller
inCategory	#item	#category
knows	#person	#person
sells	#seller	#product #service

Table 1: Ontecom Properties

Typical advantages afforded by the codification of the knowledge in an ontology are:

1. *Semantic interoperability*: Semantic mappings can be made between classes in the ontecom ontology and classes in other ontologies. For example, the *ontecom:person* class can be mapped to the *foaf:Person*, enabling the application of the attributes that define *foaf:Person*, as the range or domain, to the *ontecom:person* class.
2. *Extensibility*: The knowledge encapsulated in the ontology can be extended by referencing concepts in other ontologies. For example, the OpenCYC ontology can be used to make common knowledge assertions about the products that are on the e-commerce platform.
3. *Inference*: This is the ability to extract implicit facts from the knowledge base. The ontology languages used on ontecom are processable by an inference engine, to the extend of the inference rules implemented in the engine.

Another advantage is realized through the use of RDF as the KR language for this specific ontology. RDF is based on XML and therefore is extensible. This is in contrast to third party, or proprietary KR languages.

This ontology provides an adequate infrastructure on which to build the tools and applications necessary to provision an e-commerce service. One of the tools, mCom client, that is implemented in this PIASK based e-commerce architecture, is a J2ME based m-commerce client that enables the uploading of products' information onto the platform, by the entrepreneurs and the sellers.

C. Implementation

The mCom client (Fig. 4) targets cellphones with JAVA capabilities which are more and more common, and provides a mobile solution that can be deployed in regions with basic data cellular networks (e.g., GPRS, EDGE). mCom allows the sellers to promptly upload information regarding their products for sale onto the platform.

The mCom client is implemented on the J2ME MIDP 2.0 profile using the CLDC 1.0 configuration. It utilizes the Mobile Messaging API 2.0 (JSR 205), Mobile Media API (JSR 135) and also the Bluetooth/OBEX for J2ME (JSR 82), for a possible data transport protocol in cases of close proximity with the ontology servers.



Figure 4. mCom J2ME client

The envisaged usage scenarios of the mCom client include:

1. A seller records the information about a specific item (product or service) and they immediately upload the information on the e-commerce server using EDGE, GPRS or 3G.
2. A seller records item information on the cellphone and due to proximity to the e-commerce platform OBEX server, uses Bluetooth to upload the

information.

3. A seller records item information and stores it on the phone, using the J2ME RMS functionality, and later does a batch upload of the information stored on the phone. This is to enable cost-saving, where synchronization can be delayed until a Bluetooth upload is possible.

On the submission of the form event, the data is sent through an HTTP POST method to the back-end PHP agent which handles the following actions:

1. Formatting of the received information into RDF syntax (Fig. 5).
2. Establishing a connection to the stored ontology.
3. Adding the new product turtle to the ontology.
4. Committing the ontology to the knowledge store.

The back-end infrastructure is facilitated by Rdf API for PHP (RAP). RAP is a semantic web toolkit for PHP and it provides two APIs for handling ontology graphs, the Model API and the ResModel API [13]. The Model API is a statement-centric interface for adding, deleting and replacing statements inside a model; four different implementations are provided, based on the choice of storage (in memory or in a database) and based on the inference requirements (forward-chaining or backward chaining). The ResModel API simply provides a resource-centric view (objects with properties) on the underlying Model API implementation. In the implementation of the ontecom solution, a ResModel with database persistence is utilized and initialized as follows:

```
$conmodel = ModelFactory::getResModel(DBMODEL,
    ontecom);
$conmodel->setBaseURI(ontecom);
```

The ResModel API then allows for the addition of product details in a manner that is akin to the OOP concept of specifying object attributes. In RAP, this is achieved as follows:

```
$tmpProperty = $conmodel->createProperty(ontecom,
    "hasSeller");
$tmpObject = $conmodel->createResource
    ($_POST['seller']);
$product->addProperty($tmpProperty, $tmpObj);
```

When all the attributes have been added to the DBMODEL, it is committed to the database:

```
$db->putModel($conmodel, ontecom);
```

Once the information is committed to the ontology, it is accessible and processable by the e-commerce front end.

The current implementation of RAP has limited inference capabilities on the ResModel (vs. the InfModelF and InfModIB) and so implicit knowledge extraction is limited in this implementation (Other inference engines can be utilized on the underlying ontology to achieve the usage level desired per end-user web applications).

```
Source Code
<owl:Class rdf:ID="category"/>
<product rdf:ID="cell_phone">
  <hasComment rdf:datatype="&xsd:string"
    >this cell phone was found somewhere on the street</has
  <hasPrice rdf:datatype="&xsd:float">98.43</hasPrice>
  <hasDescription rdf:datatype="&xsd:string">nokia gsm phor
  <hasName rdf:datatype="&xsd:string">nokia 1234</hasNa
  <hasQuantity rdf:datatype="&xsd:int">5</hasQuantity>
  <hasImage rdf:datatype="&xsd:string">pic3.jpg</hasImage
  <hasSeller rdf:resource="#nokzola"/>
  <inCategory rdf:resource="#electronic"/>
</product>
<category rdf:ID="crafts">
  <hasCategoryItems rdf:resource="#bracelet"/>
  <hasCategoryItems rdf:resource="#wood_elephant"/>
  <hasCategoryItems rdf:resource="#drum"/>
  <hasCategoryItems rdf:resource="#necklace"/>
</category>
<category rdf:ID="decor"/>
<product rdf:ID="drum">
  <rdfs:comment rdf:datatype="&xsd:string"
    >this is the african bamboo drum</rdfs:comment>
  <hasComment rdf:datatype="&xsd:string"
    >this is the africa bamboo drum</hasComment>
  <hasPrice rdf:datatype="&xsd:float">0.0</hasPrice>
  <hasPrice rdf:datatype="&xsd:float">4.4</hasPrice>
  <hasDescription rdf:datatype="&xsd:string"
    >the drum has been made for the traditional xhosa dance
  <hasName rdf:datatype="&xsd:string">bamboo drum</has
  <hasQuantity rdf:datatype="&xsd:int">5</hasQuantity>
  <hasImage rdf:datatype="&xsd:string">pic1.jpg</hasImage
  <hasSeller rdf:resource="#nokzola"/>
  <inCategory rdf:resource="#crafts"/>
</product>
... ..
```

Figure 5. RDF encoded product information

D. Ontecom: The PIASK Advantage

The implementation of this e-commerce function demonstrates the population of the ontecom ontology, which resides in the KB layer of the PIASK architecture. On top of this layer are four other layers that facilitate the processing of multimedia knowledge repositories which are accessed multi-modally. Although not complete at the time of writing, these four layers, coupled with suitable layer-dependent descriptions, will handle the servicing of e-commerce content to the customers.

V. CONCLUSION

The design and implementation of the e-commerce ontology and the associated tools and services, represents an initial demonstration of the sufficiency of the PIASK model as a service implementation framework for knowledge based applications. The PIASK model facilitates the implementation of semantically rich applications and services that integrate the knowledge and model the social

systems of the local community in which they are deployed. The opportunity afforded by this model is the ability to integrate external ontologies into the local applications through standard KR languages and through the OKBC interface that connects to various knowledge bases. This architecture also leverages the multiplicity of end user devices to provide multi-modal access to heterogeneous multimedia data.

ACKNOWLEDGMENT

The financial assistance from the Andrew Mellon Foundation is hereby acknowledged. This work is undertaken in the Distributed Multimedia Center of Excellence at Rhodes University with financial support from Telkom SA, Business Connexion, Comverse, Verso Technologies, Tellabs, StorTech, THRIP, NRF, Mars Technologies, Bright Ideas 39, and Amatole Telecommunication Services.

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