The European Seaman's Smart Card: a Prototype of a Distributed System Allowing Secure Access to a Unified Representation of Maritime Records

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Abstract: - In the last decades, the field of maritime transports has been characterized by an exponential growth in terms of both people and wares moved and/or exchanges. Nevertheless, advancements in employment and business opportunities have not always been accompanied by adequate actions regarding education and training. The result is a scenario characterized by a lack of qualified seafarers in which, in addition, unhomogeneity in competence frameworks, training programs and certification modalities makes mobility across countries an extremely critical task. Such issues have been recently addressed by the O.R.S.A. M.I.NO.R.E. project, whose aim is to develop a reference scenario for the certification of seaman achievements through the use of a shared formal language within a distributed Web based environment relying on smart card technology. In this paper, the preliminary results of this project are discussed, by analyzing the formalization methodology being pursued, and providing the details of the so called electronic European Seaman's Book prototype architecture.

Key-Words: - Smart card, ontology, Seaman's Book, distributed knowledgebase, qualification profiles, certification methods

1 Introduction

Sea has always represented the central mean for the exchange of wares and people across countries. In particular, during the centuries, Mediterranean (and, in general, European) countries built up their wealth and strength by exploiting the numberless opportunities offered by the sea as a transport mean. Even today, the European Union is the world leading commercial power, and exchanges almost all its goods by the sea. The European maritime transport sector is flourishing, and handles the largest naval fleet in the world. In this perspective it is quite easy to foresee, in the mid-long term, a further development in this field, mainly determined by technological and organizational innovations, by an increase in the commercial exchanges, and by the ever growing shift to sea transports as an effective alternative to road transports. Despite this promising scenario, the present framework is characterized by a worrying lack of qualified seafarers, as well as by extreme difficulties in the recognition of existing qualifications. In fact, in the field of maritime transports, different working contexts can be identified. Moreover, with respect for example to a particular ship's size and field of employment, several areas can be distinguished (i.e. shipping, fishing, cruising, etc), which are in turn further specialized, depending on the particular navigation type or the specific goods being transported. Within the above scenario, the present educational offer is not able to completely satisfy the professional needs which emerge from the sector stakeholders, and do not prove to be adequate with respect to times and requirements of a labor market that is undergoing extremely rapid changes. Furthermore, recognition and certification of qualifications is an extremely hard task, especially when a heterogeneous transnational scenario, characterized by high-frequency mobility phenomena, has to be necessarily considered. To partially address the above difficulties, the international maritime transport field proposed the IMO-STCW'78/'95 convention, with the final aim of improving and homogenizing the lowest standards of education and professional competences for the seamen. However, IMO-STCW'78/'95 recommendations have to be approved on a national basis, and there exists countries in which they have not been confirmed yet. Nevertheless, it is worth observing that, today, the ship is no longer considered as a simple transport mean, but it is going to be intended as a true enterprise. Thus, required professional figures are expected to further evolve, in order to be able to (re-)interpret the so called "navigation process", in which ever more complex and articulated knowledge, skills and competences (KSC) not addressed by recent regulation will become to be

requested. Finally, at the present time, seafarers' related data are recorded in paper based format in a document called Seaman's Book (SB), that has to be manually annotated according to rules determined on a national basis. The overall framework depicted above results into a wide unhomogeneity, that could possibly hinder the expected growing trend. To solve these issues, European strategies pass through the adaptation of the education programs to the new needs, the integration among national systems, and the improvement of training methods. Bearing in mind the recent experiences in similar application fields, these steps are expected to be accompanied by the introduction of ICT solutions (i.e. smart cards, digital signature, Web applications, etc.), capable of enhancing seaman training and certification tasks toward the *eGovernment* direction.

2 The O.R.S.A. M.I.NO.R.E. project

Recently, the aspects above have been addressed by the O.R.S.A. M.I.NO.R.E. project (http://www.orsaminore.eu), funded under the European *Leonardo da Vinci* programme. The main project goal is to make seaman qualifications and achievements (today recorded in papery format) readable not only at the national, but also at the international level. At the same time, the project aims at making certifications spendable into a wider context, through the adoption of transparency measures based on a *unified model* for the description of seaman professional profiles, shared through the use of *smart card* technology.

A smart card, or integrated circuit card, is a pocket-sized card that embeds some kind of integrated circuits to safely handle electronic information [1,3]. In the last years, smart card technology has been successfully exploited in many application fields, since it proved to be capable of providing an effective mean for carrying out any possible kind of electronic transactions in a flexible, secure, and standard way [1,3]. Thus, electronic purse systems started relying on smart card devices, thanks to their enhanced security capabilities [6]. Afterward, smart card based solutions becomes increasingly popular for e-commerce applications [5]. Recently, such kind of technology has been effectively deployed to support wide spectrum e-government initiatives, resulting into the introduction of smart card in identification schemes at both national and international levels (citizen, drivers' licenses, and health cards [2, 4]).

In the unifying strategy proposed by O.R.S.A. M.I.NO.R.E., the smart card becomes the mean to migrate existing national-wide SBs into an electronic tool providing seamless and secure access to a Web based distributed repository of seafarer records, thus guaranteeing an effective traceability of the seaman education and training path. Migration has to be supported by a suitable re-definition of existing information into a shared knowledge base, relying on a univocal description language (i.e., an "ontology") capable of providing, from the conceptual point of view, the unifying factor favoring a shared understanding of national semantics at the transnational level. In this paper, the preliminary results of the above project are summarized. In particular, the present structure of national SBs is discussed in Section 3, while the methodology for the construction of the shared ontology is analyzed in Section 4. The organization of the Web based architecture, and the features of the O.R.S.A. M.I.NO.R.E. smart card are presented in Sections 5 and 6, while conclusions are given in Section 7.

3 National Seaman's Book Information

In a preliminary phase of the O.R.S.A. M.I.NO.R.E. project information related to existing paper based SBs from the various European countries represented in the partnership (namely Greece, Italy, Netherlands, Romania, Slovenia, Spain, and Turkey) were collected, together with reference material, i.e. official documentation, national regulations, international agreements, etc. The goal of this phase was to achieve a broad knowledge of the transnational scenario, while at the same time developing a comprehensive vocabulary of the terminology in use within the considered context (to be later used for the construction of both the distributed database, as well as the shared ontology). Then, national SBs were individually analyzed, and the main constituting elements were identified. With the aim of improving collaboration and achieving a high degree of mutual understanding overcoming national barriers, a formal description providing hidden details behind each SB was produced. The above description relies upon the well known UML (Unified Modelling Language) class diagrams, that allow to formulate a structured view of a particular context of interest by means of classes (i.e. aggregators of instances, or concrete elements belonging to the domain under analysis) and associations (i.e. relationships among classes/instances). For each SB, all the characterizing sec-

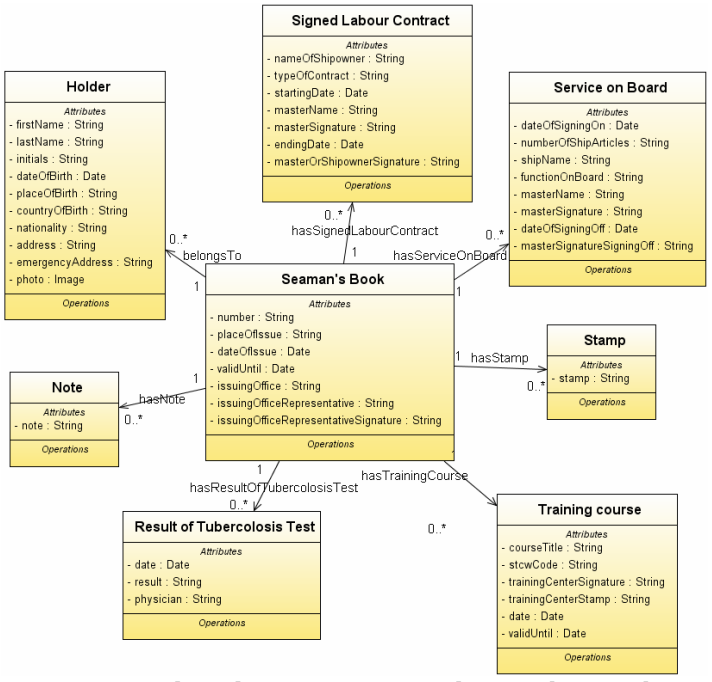

Fig. 1. UML class diagram corresponding to the Dutch SB.

Field summ. from Seaman's Book	SI	ES	TK	RO	NL	IT	GR	UML attribute
Name of the ship	✓	✓	✓	✓	✓	✓	✓	shipName
Port of registry	✓					✓	✓	shipRegistrationPort
Registration number		✓	✓			✓	✓	shipRegistrationNumber
Flag country	✓							
Type of the ship	✓		✓	✓		✓	✓	shipType
Gross tonnage	✓		✓	✓		✓	✓	grossTonnage
Engine Power	✓		✓	✓		✓		enginePower
Type of navigation	✓					✓		
Position/Function/Rank/Assignement	✓		✓		✓	✓	✓	rank
Port of embarkation	✓	✓	✓			✓	✓	embPort
Date of embarkation	✓	✓	✓	✓	✓	✓	✓	embDate
Name of auth. person at emb.	✓	✓			✓	✓		embAuthPersonName
Signature of auth. person at emb.	✓	✓			✓	✓		embAuthPersonSignature
Authorized seal at embarkation	✓					✓		
Maritime Captaincy at emb.		✓						
Ship articles	✓				✓		✓	
Muster-roll						✓		
Muster-roster						✓		
Date of issue						✓		
Place of issue						✓		
Destination						✓		
Port of disembarkation	✓	✓				✓	✓	desPort
Date of disembarkation	✓	✓		✓	✓	✓	✓	desDate
Reason	✓	✓				✓	✓	reason
Name of auth. person at dis.	✓	✓	✓			✓		desAuthPersonName
Signature of auth. person at dis.	✓	✓	✓		✓	✓		desAuthPersonSignature
Authorized seal at dis.	✓					✓		
Maritime Captaincy at dis.		✓						

Table 1. Insert caption here Insert caption here Insert caption here Insert caption here Insert caption here.

tions were "dissected", and core conceptual elements (i.e. fields) were identified. In the diagrams being generated, SB sections were mapped onto UML classes, while section fields were mapped onto class attributes. Class names roughly correspond to SB's section headlines, while attributes names were defined by summarizing the possibly extended meaning of the particular field. As a matter of example, the UML class diagram produced for the Dutch SB is illustrated in Fig. 1. In all the UML diagrams being produced, a central role is played by the "Seaman's Book" class/concept that represents a sort of container for the remaining concepts. In each SB, this class provides essential information (i.e. book number, date and place of issue, etc.), and presents connections with the other classes, which are depicted using UML navigational associations characterized by a name, as well as by two multiplicity pairs.

4 The Construction of a Common Model

As mentioned in the previous section, the modelling phase carried out on national SBs was mainly devoted at achieving a knowledge of the "state-of-the-art" concerning the present solutions enabling the certification of seafarer qualifications/entitlements, as well as the associated history. However, since the final aim of O.R.S.A. M.I.NO.R.E. is the construction of a smart card based shared "view" of the same concepts, capable of providing improved support for the mobility of workers (while fostering at the same time lifelong learning scenarios), each particular national model was compared with the others, trying to find similarities, as well to unveil differences. This task was executed simultaneously over multiple SB sections, since the same information is not recorded in exactly the same section in different SBs. Moreover, because of national specificities (due to *subsidiarity*), it emerged that not all the SBs require to store the same information (and in the same way). For instance, the Italian SB is by far the most "complete" document in terms of sections, but the format for filling-in specific fields of a section is often left to the particular Port Authority and/or ship's master, and this can result in possible ambiguities. On the other hand, Turkish and Romanian SBs are two examples of very synthetic documents, where only essential data are recorded, into a very strict format. The result of this analysis/comparison on the section related to onboard services is shown in Table 1, where the first column tabulates the fields that can be brought back to the context of interest (the actual name is a summary of the field meaning). In columns from two to eight, a check mark indicates the presence/absence of the specific field (for countries indicated in the first row). It is worth observing that by considering each single row individually, the number of check marks provides an indication of the importance of a particular field in a transnational vision. With the aim of creating a European

```
<?xml version='1.0' encoding='UTF-8'?>
<librettoDiNavigazione>
 <movimentiDiImbarcoSbarco>
  <movimento>
  <luogoDiImbarco>Imbarco</luogoDiImbarco>
  <dataDiImbarco>Data imb.</dataDiImbarco>
  <inQualitaDi>Funzione</inQualitaDi>
  <tipoDiNave>Tipo nave</tipoDiNave>
  <denominazioneNave>Denom.</denominazioneNave>
  <numRegistrazioneNave>Iscr.</numRegistrazioneNave>
  <registroNave>Registro</registroNave>
  <potenzaApparatoMotore>Pot.</potenzaApparatoMotore>
  <stazzaLorda>Stazza lorda</stazzaLorda>
  <ruoloDEquipaggio>Ruolo</ruoloDEquipaggio>
  <ruolinoDEquipaggio>Ruolino</ruolinoDEquipaggio>
  <luogoDiRilascio>Luogo rilascio</luogoDiRilascio>
  <dataDiRilascio>Data rilascio</dataDiRilascio>
  <destinazione>Destinazione</destinazione>
  <nomePersonaAutImbarco>Inc.</nomePersonaAutImbarco>
  <firmaPersonaAutImbarco>Fir.</firmaPersonaAutImbarco>
  <timbroImbarco>Timbro aut. comp.</timbroImbarco>
  <luogoDiSbarco>Porto di sbarco</luogoDiSbarco>
  <dataDiSbarco>Data di sbarco</dataDiSbarco>
  <motivo>Motivo dello sbarco</motivo>
  <tipoDiNavigazione>Navigazione</tipoDiNavigazione>
  <nomePersonaAutSbarco>Inc.</nomePersonaAutSbarco>
  <firmaPersonaAutSbarco>Fir.</firmaPersonaAutSbarco>
  <timbroSbarco>Timbro aut. comp.</timbroSbarco>
  </movimento>
 </movimentiDiImbarcoSbarco>
</librettoDiNavigazione>
```

Fig. 2. Formal description of an excerpt of the Italian SB.

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform" version='1.0'>
 <xsl:template match="/">
 <seamanBook>
  <servicesOnboard>
    <xsl:for-each select="librettoDiNavigazione/movimentiDiImbarcoSbarco/movimento">
     <service>
      <shipName><xsl:value-of select="denominazioneNave"/></shipName>
      <shipType><xsl:value-of select="tipoDiNave"/></shipType>
      <shipRegistrationPort><xsl:value-of select="registroNave"/></shipRegistrationPort>
      <shipRegistrationNumber><xsl:value-of select="numRegistrazioneNave"/></shipRegistrationNumber>
      <grossTonnage><xsl:value-of select="stazzaLorda"/></grossTonnage>
      <enginePower><xsl:value-of select="potenzaApparatoMotore"/></enginePower>
      <rank><xsl:value-of select="inQualitaDi"/></rank>
      <embPort><xsl:value-of select="luogoDiImbarco"/></embPort>
      <embDate><xsl:value-of select="dataDiImbarco"/></embDate>
      <embAuthPersonName><xsl:value-of select="nomePersonaAutImbarco"/></embAuthPersonName>
      <embAuthPersonSignature><xsl:value-of select="firmaPersonaAutImbarco"/></embAuthPersonSignature>
      <desPort><xsl:value-of select="luogoDiSbarco"/></desPort>
      <desDate><xsl:value-of select="dataDiSbarco"/></desDate>
      <desAuthPersonName><xsl:value-of select="nomePersonaAutSbarco"/></desAuthPersonName>
      <desAuthPersonSignature><xsl:value-of select="firmaPersonaAutSbarco"/></desAuthPersonSignature>
    </service>
   </xsl:for-each>
  </servicesOnboard>
 </seamanBook>
</xsl:template>
```

Fig. 3. A portion of the XML transformation stylesheet for translating the Italian SB schema to the European common model.

wide SB, two approaches are feasible: to define a omni-comprehensive container capable of recording data from all the possible national records, or to identify a common subset of fields capable of providing sufficient information. According to the homogenizing approach being pursued, in the O.R.S.A. M.I.NO.R.E. project the second strategy was chosen, by at the same providing a way for preserving national specificities. In this case, the term "sufficient" needs an additional explanation. In fact, it has to be considered that current SBs are based on existing regulations which are established on a national basis. Thus, no field can be removed without losing the necessary expressiveness of the particular SB. Thus, at the present time, the term sufficient means that, in almost all the cases, the selected subset should be able to guarantee the highest probability of successful understanding into a transnational mobility scenario. Even if this choice still acts as a proposal, on one hand it allowed for the construction of the prototype of a European wide repository. On the other hand, it will be capable of playing the role of a forerunner experience to be possibly used by forthcoming expected studies in this field.

By applying the methodology above, a subset of the original UML classes was identified, and for each class, a subset of information belonging to national SBs was extracted. For instance, an "Onboard Services" class was defined, that is characterized by the attributes reported in the last column of Table 1 (selected by applying a majority decision rule). In this way, a new UML class diagram describing the so called *European Seaman's Book* common model was defined.

The construction of a unified model representing the unified vocabulary for the considered domain was only the first half of the job. In fact, even if UML diagrams can be used for creating a shared knowledge and for supporting a mutual understanding of a considered context, in the end, the integration of the newly generated information into a computer based systems requires the expression of the model into a machine supported language. Thus, the UML diagrams and associated information were translated into XML. The reasons for the choice of the XML representation were manifold. First, a direct mapping between UML and XML can be easily defined. Moreover, the XML model preserves its human-readability, while at the same time supporting machine based processing. Finally, while UML provides a way for describing the structure of data, XML adds the possibility of expressing also contents (currently recorded into paper based SBs), which need to be migrated into the foreseen distributed repository. Thus, an UML to XML translation process was performed, by mapping both the national and the unified models into XML schemas. In a similar way, UML models were mapped onto a relational database structure (to be exploited in order to implement the necessary persistent data storage). Prototype database were created, and populated with experimental data to be exploited in order to validate overall system effectiveness.

5 The European Seaman's Smart Card

The aim of the O.R.S.A. M.I.NO.R.E. project is to extend the reach of smart card technology to a field in which frequently moving subjects (i.e. seafarers) need to bring with them essential information (including qualifications, achievements and sanitary related data, etc.) that has to be shared into heterogeneous contexts. In this framework, a strong certification scheme (which is today guaranteed by papery documents, authorized signatures and seals), is required. By moving into a computer based scenario, sensi-

```
<?xml version="1.0" encoding="UTF-8"?>
<seamanBook>
 <servicesOnboard>
 <service>
  <shipName>Denom.</shipName>
  <shipType>Tipo nave</shipType>
  <shipRegistrationPort>Registro</shipRegistrationPort>
  <shipRegistrationNumber>Iscr</shipRegistrationNumber>
  <grossTonnage>Stazza lorda</grossTonnage>
  <enginePower>Pot.</enginePower>
  <rank>Funzione</rank>
  <embPort>Imbarco</embPort>
  <embDate>Data imb.</embDate>
  <embAuthPersonName>Inc.</embAuthPersonName>
  <embAuthPersonSignature>Fir.</embAuthPersonSignature>
  <desPort>Porto di sbarco</desPort>
  <desDate>Data di sbarco</desDate>
  <desAuthPersonName>Inc.</desAuthPersonName>
  <desAuthPersonSignature>Fir.</desAuthPersonSignature>
 </service>
 </servicesOnboard>
</seamanBook>
```

Fig. 4. A portion of the common model produced by XSLT.

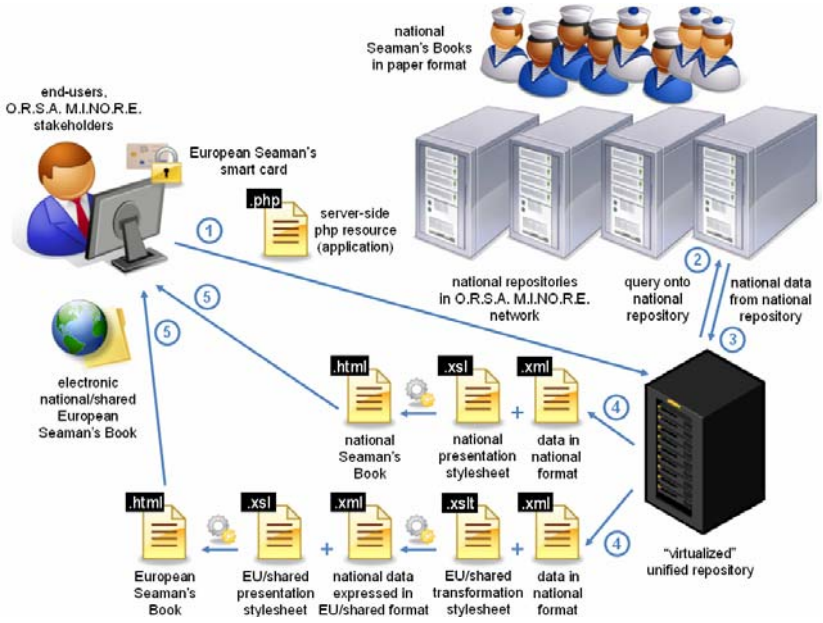

Fig. 5. Overall architecture of the O.R.S.A. M.I.NO.R.E. network. End-user can (1) access the system through a machine equipped with a Web browser and a smart card reader. A php application (2) interacts with the distributed repository and (3) produces a XML description of SB data, (4) that is then converted into a national or European (5) Web based document.

tive data confidentiality and integrity need to be guaranteed. Given the constraints above, the unifying device selected for the development of the prototype architecture was a microprocessor based smart card equipped with 64 KB of EEPROM memory and capable of efficient DES/3DES and RSA encryption/ decryption computations (Athena AseCard Crypto). A PKI infrastructure capable of handling both seamen and authorities certificates to be exploited with the aim of securely accessing the distributed repository was deployed. The surface of the plastic card possibly allows to host common identification information that can be selected by applying the above comparison approach over the "Holder" class/section (e.g., on Fig. 1). Moreover, the persistent memory has been exploited to record information which could need to be accessed even when a network connection to the proposed distributed framework is not available. In this case, data are stored (in a secure way) in the exact format of the paper based SB, thus constituting an exact replica of the national document in electronic format.

Despite the advantages in terms of privacy, the real benefits due to the introduction of smart card technology appear when this is used as an identification token for accessing the overall O.R.S.A. M.I.NO.R.E. system. In this case, the full potential of Web technologies, as well as of the proposed unified representation, is exploited. In fact, national format can be automatically translated, upon request, into a unified representation favouring recognition and transparency into a mobility scenario (see Section 6). National data not included in the shared notation can be used to enhance the probability of system adoption by sceptical authorities that can be possibly reluctant to the introduction of the novel technology. Finally, the connection to the proposed server side architecture allows to outlining the link between a national qualification and/or entitlement with respect to international certification modalities, as well as to the underlying KSC framework defined within the project.

6 Overall System Architecture

The overall system architecture is based on the widely adopted multi-tier paradigm that today represents the reference approach for building Web based applications. According to this paradigm, the O.R.S.A. M.I.NO.R.E. system can be accessed by any workstation equipped with a common Web browser, and a smart card reader. When the user logs into the system, he/she is asked to insert his own smart card (e.g. a seaman) or the smart card he/she intends to work on (e.g. a new smart card to be registered into the system). Information securely stored on the smart card are used to establish a SSL connection with the server side system. Once the secure channel is established, user's certificate recorded on the digital mean is exploited to notify the system about the actual user, and to let the remote side act in order to produce the requested information. The server side comprises a virtual data repository and an application server, playing the role of both a Web server (handling client requests and delivering responses to end-users), as well that of a service provider (bridging the gap between application logic and database). The repository is constituted by a collection of mySql databases (one for each country involved in the project), that can be distributed on a European level and physically located in the various facilities belonging to the O.R.S.A. M.I.NO.R.E. network. Each database is designed to contain only a portion of the whole knowledge base, and its logical schema (in terms of relational tables) has been generated starting from the national models presented in the previous sections. Thus, the database schema for Italy is based on a set of tables

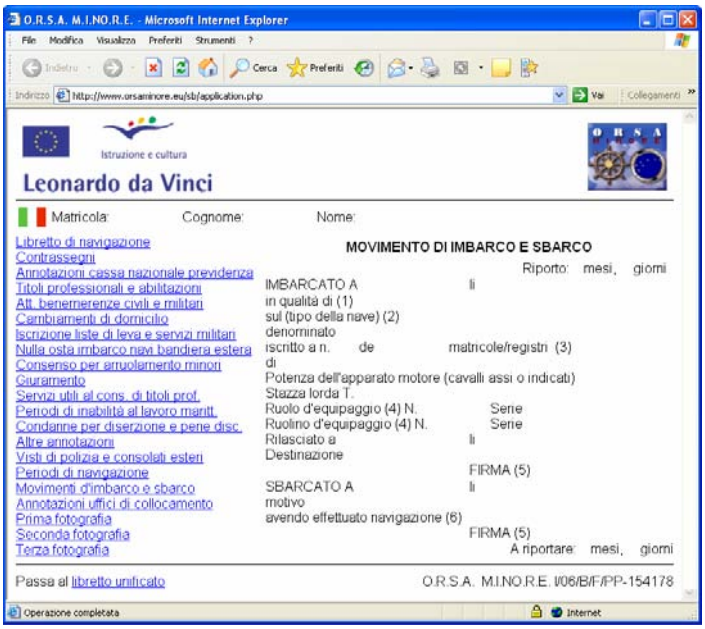

Fig. 6. A snapshot of the prototype Web based application.

whose names and attributes reflect those in the UML description. The application server has been deployed using the PHP technology (under Apache). This choice was mainly due to PHP ability in generating dynamic contents, as well as to its native support for database and XML management. The application server manages requests coming from system end-users and stakeholders which require to accessing the distributed knowledge base, and behaves as a virtual repository, masking the presence of the underlying heterogeneous data structure. In fact, it is capable of extracting the portion of information of interest to the user, and to present it in the requested format. Basically, two access strategies are possible. In the first scenario, the system is accessed by a national authority that requires a traditional (but electronic) representation of data recorded into a specific SB issued by the same country. The application server queries the national repository, and generates a visual representation mimicking the original document through dynamically generated Web pages. This is a two-step process, in which first an XML description of requested data is produced; then, an XSL stylesheet is used to map XML description into the HTML language, that can be understood by the Web browser based client. Even if this approach for Web page generation is largely appreciated for its enhanced capability of clearly separating data from representation, its real effectiveness is definitely proved when considering the second access scenario. In this second situation, an international authority which complies with the unified SB format proposed in the O.R.S.A. M.I.NO.R.E. project, connects to the system and requests data related to certified qualifications and services of a seaman holding a SB issued by a foreign country. As in the first scenario, the application server extracts a structured description of SB data encoded according to the original model (an excerpt of this description for the Italian SB is reported in Fig. 2). The dynamically generated document undergoes an XSLT transformation (Fig. 3) that translates the national description into the proposed transnational notation (Fig. 4). This step can be carried out by either removing not matching details, or by maintaining also subsidiary information capable of expressing national specificities. The resulting XML document is then processed through an XSL stylesheet that converts it into its final Web based representation (the overall architecture is illustrated in Fig. 5). The layout of the dynamically generated electronic SB allows the user to navigate records natively stored into the original/national format through a unified virtual view. Moreover, if country-specific data have been embedded into the XML based representation, the stylesheet generates separate contents that can be possibly visualized, thus integrating basic (shared) information. A sample section of the electronic document for Italy is shown in Fig. 6.

7 Conclusion

In this paper, the design of a unified repository allowing for the sharing of sensitive data related to maritime workers through a smart card based Web architecture is presented. The availability of a common vocabulary for describing traditional paper based Seaman's Books in electronic format lays the basis for the development of a transnational framework where achievements and qualifications can be mutually recognized in a transparent and seamless way.

Acknowledgement

This work was developed within the O.R.S.A. M.I.NO.R.E. "Organizzazione delle ceRtificazioni con applicazione di Smart cArd nei MestIeri e nelle inNOvazioni del maRE" project, funded under the Leonardo da Vinci programme (I/06/B/F/PP-154178).

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