The 3D Cadastre Prototype and Pilot in the Russian Federation

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SUMMARY

This paper presents the developed prototype and the planned pilot of the on-going project on 3D cadastre modelling in the Russian Federation. The aim of this project is to provide guidance in the development of 3D Cadastral registration and to create favourable legal and institutional conditions for the introduction of a 3D cadastre. The Russian Federation has a strong drive towards a 3D cadastre for better registration of complex buildings, or other types of constructions, and subsurface networks (e.g., cables and pipelines). After the recent completion of the design of a 3D Cadastral model, the project is currently in the phase of testing this design via a pilot based on the developed prototype system. The test data, including selected 3D cases, is from Nizhny Novgorod (about 400 km east of Moscow), which has been selected as pilot region in this project. The selected 3D cases are representative 3D cadastral objects related to buildings (units) and pipelines. The initial prototype focuses on the presentation of 3D information of cadastral objects. Therefore a web browser based solution has been developed, in which the 3D visualization and interaction is implemented with the BS Contact plug-in from Bitmanagement (www.bitmanagement.com). This includes functionality to: display and interact with the various pilot objects in 3D (rotate, zoom, select, etc.), connection of 3D actions to existing 2D cadastral portal (maps.rosreestr.ru/Portal), display administrative data (show id, cadastral number), alphanumerical selection on multiple attributes (owner name, id of cadastral object, address, etc.), ability to configure 'hide / show' privacy data (depending on user), show / hide layers (including reference data such as 2D cadastral map, topographic map, or areal photograph), offer link to photograph of selected 3D building, interface in Russian language, etc. The pilot will further be used to evaluate the possible future workflow around 3D parcels in Russia: accepting newly registered 3D parcels, and correctly storing them into the database for possible future access. The experiences from the pilot will be used to prepare the guidelines for the future 3D registration: both the legal aspects and the technical workflow.

РЕЗЮМЕ

В данной докладе представлена разработка прототипа и планированное пилотное исполнение по моделированию 3D кадастра в России. Целью данного проекта является руководство, внедрение и развитие 3D кадастрового учета и создания режима благоприятствования правовых и институциональных условий для внедрения 3D-кадастра. Российская Федерация сильно стремится ввести 3D кадастр для лучшей регистрации комплексов зданий, или других типов конструкций, а также подземных сетей (например, кабелей и трубопроводов). После недавнего завершения разработки 3D- кадастровой модели, проект находится в стадии тестирования через пилот на основе разработанных прототипов системы. Тест данные, в том числе избраных 3D случаев, из Нижнего Новгорода (около 400 км к востоку от Москвы), в качестве выбранного пилотного региона в этом проекте. Отдельные случаи представляют 3D кадастровые объекты, связанные с домами (частями) и трубопроводами. Первоначальный прототип посвящен презентации 3D-кадастровой информации или объектов. Разработанное решение на основе веб-браузера и все это в 3D-визуализации и взаимодействии на основе BS Контакт плагин из Bitmanagement (www.bitmanagement.com). Это включает в себе функциональные возможности: просматривать и взаимодействовать с пилотом с различными объектами в 3D (поворот, масштабирование, выбор и т.д.), связь действий для замены существующих в 2D или в 3D кадастровых порталов (maps.rosreestr.ru/Portal), дисплей административные данные (показать ID, кадастровый номер), альфа-числовой выбор по нескольким атрибутам (имя владельца, идентификатор или кадастровый объект, адрес и т.д.), возможность настройки "скрывать / показывать" конфиденциальные данные (в зависимости от пользователя), показать / скрыть слои (в том числе исходные данные, такие как 2D Кадастровая карта, топологические графические карты или аэрофотосъмки), предлагая связать фотографию или выбранного 3D-здания, на русском языке интерфейса и т.д. пилот будет использован для дальнейшей оценки возможных будущих работ по 3D участкам в России: принятие новых зарегистрированных 3D посылок, и ввод их в базу данных правильно для возможного будущего доступа.Опыт пилота будет способствовать подготовки руководящих принципов для будущей 3D-регистрации: как для правовых аспектов, так и для технического документооборота.

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1. INTRODUCTION

This paper presents the 3D Cadastre prototype development and the set-up of the pilot in the Russian Federation. The context and scope of this project have been published earlier, including a selection of typical 3D cases to be registered (Vandysheva et al, 2011a and 2011b). After the initial analysis of the Russian legislation, an inventory of possible use cases in Russia, the examination of 3D Cadastre solutions in other countries, and the design of a 3D Cadastral model, the project is currently in the phase of the development of a prototype and putting this to practice in the context of a pilot. The project is based on experience of the Netherlands (Stoter and Van Oosterom, 2005) and other countries (van Oosterom et al, 2011). Our analysis showed that the cadastral law in the Russian Federation is quite generic concerning 3D situations: it neither explicitly mentions 3D, nor does it prohibit 3D volumetric parcels for registration. The Russian Federation has a strong drive towards a 3D cadastre for better registration of complex buildings, or other types of constructions, and subsurface networks (e.g. cables and pipelines).

The current cadastral parcel registration system is 2D polygon-based, in the terminology of the LADM (ISO DIS 19152, 2011). The database contains the full history of the parcel since its creation. The scale of the cadastral maps differs from 1:2,000 in urban areas up to 1:10,000 in rural areas. The Russian Cadastre registers more than land parcels. According to article 1 of the Federal Law 'On State Cadastre for Real Estate' the Russian cadastre (maintained by Rosreestr) registers five types of objects: 1. Land (parcels), 2. Buildings, 3. Apartment Units, 4. Other structures (bridges, pipelines etc.), and 5. Unfinished objects, i.e. objects under construction (buildings, bridges, pipelines, etc.). The implementation of this model, both the administrative (legal) and spatial parts, is realized via the two existing databases of Rosreestr. The spatial and legal information on parcels can be accessed online by the public (http://maps.rosreestr.ru/Portal/). Rosreestr falls under the authority of the Ministry of Economic Development of the Russian Federation.

The design of the 3D Cadastral model is based on the ISO 19152 Draft International Standard (DIS) Land Administration Domain Model (LADM) as a reference model. This already includes a 3D spatial profile. In an earlier phase of the project it has become clear that there is no need to change the legal/administrative part of the model (Vandysheva et al, 2011b). It was decided that the 3D registration is based on two types of objects 1. 3D polyhedron volume (flat planes) and 2. 3D multicurve with diameter (curved surfaces around pipelines). The 3D volume parcels have their own geometry, similar as in the current 2D database (via polygons). So, the advantages are clear: relatively easy implementable with current technology (database, GIS/CAD), and similar to polygon approach in 2D. During data entry careful checks have to be implemented to validate that 3D volume parcels are well formed and non-overlapping. The

3D polyhedrons do fit in the Oracle spatial SDO_GEOMETRY type (as well as 2D polygons do) and Oracle has good functionality to validate the 3D volume parcels. Oracle does call this a geometry subtype and the name for a polyhedron is a ‘solid’.

It is crucial to have guidelines describing how the 3D parcels must be submitted for registration. These guidelines have been described in (Vandysheva et al, 2011b) and are based on experiences in other countries especially the Queensland ‘Directions for the Preparation of Plans’ (Queensland Government, 2008). The actual encoding of the 3D Parcel, as part of the initial registration/survey plan, will be done in the XML standard format according to the integration of LADM-3D (ISO, 2011) and CityGML, the OGC standard for 3D city objects based on GML (OGC, 2007); see Figure 1. This solution allows combining a 3D cadastral object (e.g. LA_LegalSpaceBuildingUnit from LADM) with its physical counterpart (e.g. part of building CityGML).

After this introduction, this paper now continues with the explanation of the prototype in Section 2. The set-up of the pilot is described in Section 3. The paper ends with concluding remarks and future work in Section 4.


```xml
<?xml version="1.0" encoding="utf-8"?>
<CityModel xmlns="http://www.opengis.net/citygml/1.0" ...>
<gml:name>TU Delft example 3D Parcel for Cadastre</gml:name>
 <gml:boundedBy>
   <gml:Envelope srsDimension="3" srsName="urn:ogc:def:crs:EPSG:7.6:7415">
   <gml:lowerCorner srsDimension="3">84936.169 444962.883 0.0 </gml:lowerCorner>
   <gml:upperCorner srsDimension="3">86082.217 446807.742 90.0 </gml:upperCorner>
  </gml:Envelope>
 </gml:boundedBy>
 <cityObjectMember>
  <generic:GenericCityObject gml:id="Parcel_1">
   <creationDate>2011-04-01</creationDate>
   <generic:class>LA_LegalSpaceBuildingUnit</generic:class>
   <generic:lod4Geometry>
    <gml:Solid>
     <gml:exterior>
      <gml:CompositeSurface>
       <gml:surfaceMember>
        <gml:Polygon>
         <gml:exterior>
          <gml:LinearRing>
           <gml:pos>85514.91 445173.489 0.0</gml:pos>
           <gml:pos>85511.709 445170.399 0.0</gml:pos>
           <gml:pos>85510.892 445172.368 0.0</gml:pos>
           <gml:pos>85514.066 445175.521 0.0</gml:pos>
           <gml:pos>85514.91 445173.489 0.0</gml:pos>
          </gml:LinearRing>
         </gml:exterior>
        </gml:Polygon>
       </gml:surfaceMember>
...

      </gml:CompositeSurface>
     </gml:exterior>
    </gml:Solid>
   </generic:lod4Geometry
  </generic:GenericCityObject>
 </cityObjectMember>
</CityModel>
```


Figure 1. Example XML encoding of 3D Parcel as LADM class 'LA_LegalSpaceBuildingUnit' in CityGML using gml:Solid (defined by gml:linearRing’s, not all displaced).

2. 3D CADASTRE PROTOTYPE

The prototype has been designed to optimize the user experience during dissemination (and does not support other tasks such as initial registration, validation and data management). Subsection 2.1 discusses the data preparation, Subsection 2.2 explains the prototype architecture, while Subsection 2.3 shows the main functionality.

2.1 Data sets

The test data consist of three cases from Nizhegorodskaya Oblast, which has been selected as pilot region in this project. Besides the 3D cadastral parcels and related administrative (legal) information, each case also includes terrain elevation, 2D cadastral parcels, 2D reference topographic data, 3D reference models (buildings), and digital photographs. The following cases have been created: Case 1 is the Teledom building (which has interesting overhangs), Case 2 is the apartment complex (a more "normal" 3D configuration for housing and non-residential purposes) and Case 3 is a short underground gas pipeline crossing a number of parcels. In the prototype for every case two XML files are created: one with legal (administrative) data, such as rights and owners and one with 3D geometric data (in X3D encoding ISO/IEC, 2007, ISO/IEC, 2008).
The data, both administrative and spatial, have been prepared in various formats and by using a range of tools: Google SketchUp (sketchup.google.com), Microsoft Excel (administrative data), X3D-Edit (savage.nps.edu/X3D-Edit), an XML editing tool (for example oXygen, www.oxygenxml.com), ArcGIS/ArcScene from ESRI (www.esri.com), FME from SAFE Software (www.safe.com), and several own scripts for converting XML-based files. For each floor of a building there is a component-object, which contains the following: floor plan (group-object with 3D polylines), 3D cadastral objects (solid group-objects) with 'apartment_nr'-attribute, and walls (solid group-object). The 3D objects are created by using Google SketchUp and georeferenced via the topographic map. The SketchUp file is converted to X3D (via Collada and X3D-Edit). Finally, the X3D-file is extended for use in the prototype with touch-sensors (tooltips), plane-sensors, switches, default calculated viewpoints (looking east, south, west, north), references to the other datasets (terrain elevation, parcels, topographic map) and JavaScript (for event handling).

2.2 Prototype development

As indicated above, the functional focus is on visualization and user interaction within a 3D viewer. The prototype has been developed as extension of the existing 2D portal with a link to the new 3D viewer; see Figure 2. The main technical components are the database, the webserver and the 3D web browser. In the prototype the 3D geometry is prepared in (static) X3D files (for geometry) and corresponding administrative information in additional XML files. In the future production environment these XML/X3D files will be generated dynamically from the databases. At each location where 3D information is available in the prototype, an icon is added to the 2D cadastral map. To show the corresponding 3D-objects, the user has to click on the icon. The first time that the 3D web browser is used, the installation of an X3D-plugin (BS Contact from Bitmanagement, www.bitmanagement.com) in the web browser is needed.

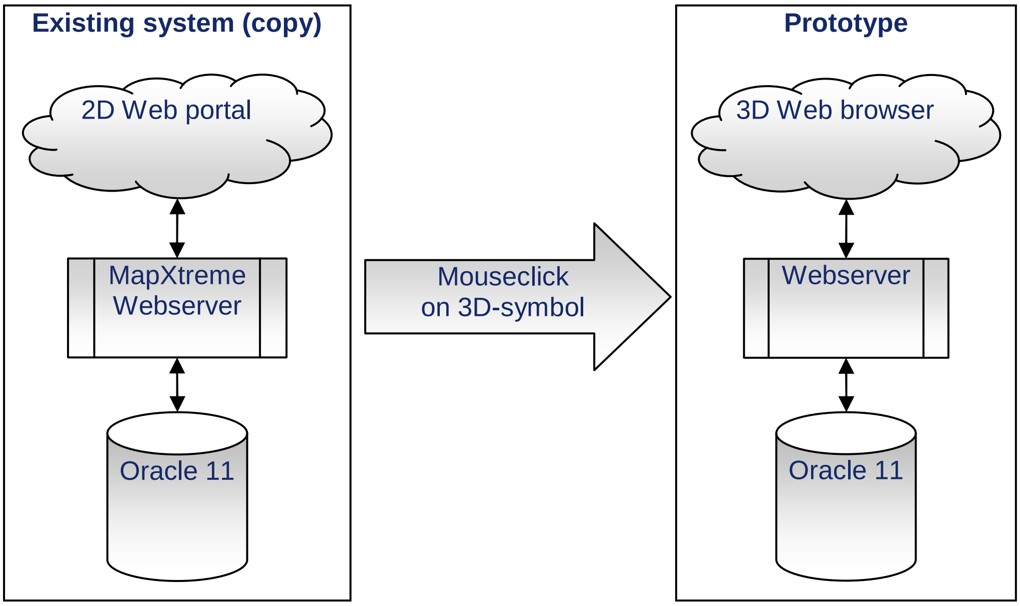

Figure 2. The 3D viewer as extension of the current 2D portal.

2.3 Functionality

In Figure 3 the interface of the prototype is shown, which consist of 3 parts: 3D viewer (left), selection (lower right) and result display (upper right). Within the 3D viewer, the 3D objects can be rotated, inspected and manipulated. The options below the viewer can be chosen to switch certain layers on or off (topographic map, floor plans, walls, ground parcels and DTM), or to switch between the identify-mode and the move-floor-mode.
When the cursor is positioned over a 3D parcel, the tooltip will give some information about the object (cadastral number). If you click on a 3D parcel, the detailed information about this parcel will show up in the result display in the upper right part of the window. Note that for the pipeline this information is different (see Figure 4) than for the building unit. The lower right part is for specifying administrative selections (based on owner, type of right, size, etc.), the results will be shown in the upper right part and highlighted in the 3D viewer. Any combination of attributes can be used to specify the selection and dropdown lists show all available options to choose from for each of the attributes. The button 'clear selection' can be used to reset the selection, removing the highlighting from the 3D viewer and clearing the results. When in the move-floor-mode, the mouse can be used to drag out any floor of the building, showing the 3D parcels inside the building; see Figure 5.
Via a configuration file (also XML) it is possible to specify the text of the labels in the interface (e.g. provide English or Russian labels) and to hide certain attributes (e.g. for privacy reasons, depending on the user).

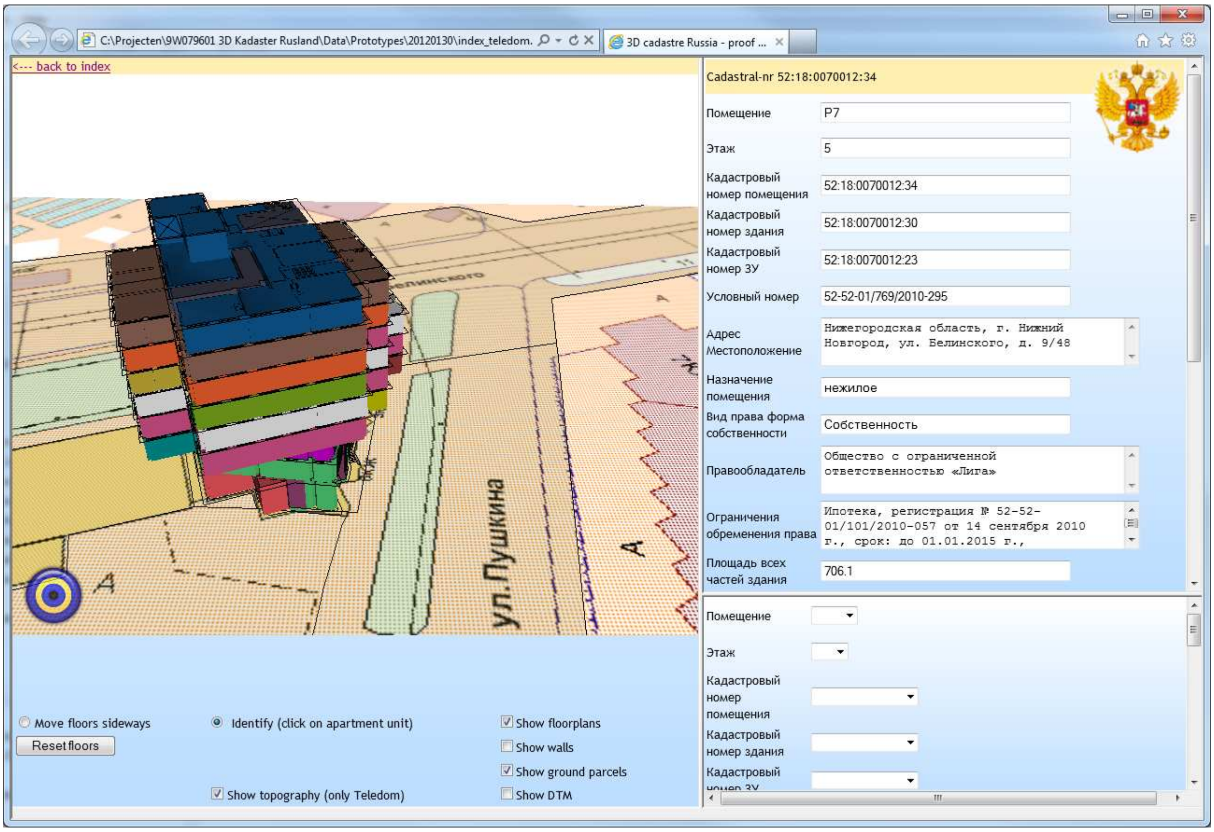

Figure 3: With data from Case 1 the interface of the prototype is shown: 3D viewer (left), selection (lower right) and result display (upper right).

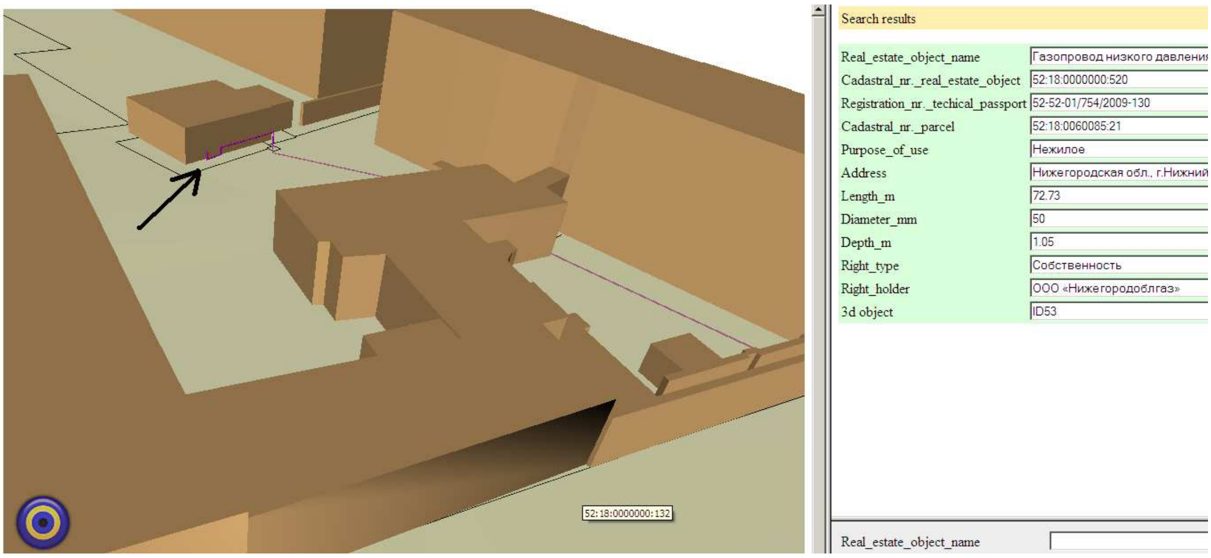

Figure 4: Case 3, the pipeline (the purple line, starts above ground near arrow and is partly below ground, but this is only/better visible in interactive mode by looking above and below the surface). When the pipeline is selected different attributes are displayed (compared to apartments); e.g. length and diameter.

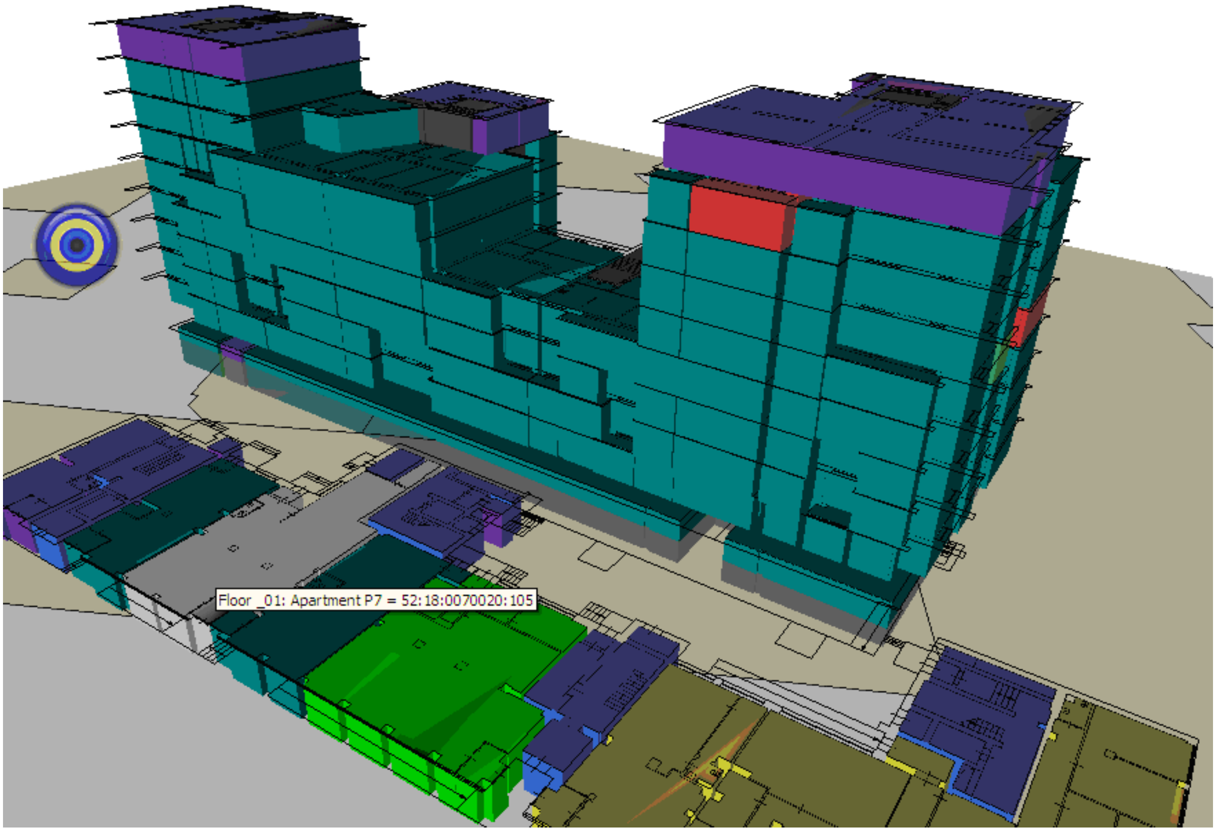

Figure 5: Case 2, Floor_01 dragged outside the building. Note the tooltip which contains the identifier of the object during move-over (apartment P7) and also note that the floor plan is dragged simultaneously with the 3D parcel (for reference purpose, but this layer can be switched off)

3. PILOT IN THE RUSSIAN FEDERATION

Conducting the pilot contributes to three main goals. The first goal is to provide the stakeholders with a better understanding of the benefits of a 3D Cadastre in Russia. The second goal is gaining insight within the project team about opportunities, pitfalls and limitations of a 3D Cadastre. The third and final goal is getting experience on the actual implementation of a 3D Cadastre. The pilot consists of one day "active" pilot and two weeks "passive" pilot (both planned for April 2012). The active pilot will be performed with a small group of participants from relevant stakeholders from Rosreestr and affiliated organisations. At end of the day, an extensive evaluation with the participants will be held. The participants have the chance to use the prototype, for example to demonstrate to others or when participants are interested in exploring the possibilities further. They also will have the opportunity to provide input on desired future developments. The participants of this part of the pilot are also from outside Rosreestr: utility companies, notaries, real estate agents or general public. The pilot will be evaluated after the two weeks of "passive pilot". The evaluation is based on the experiences of the participants and on the experiences of the project team.

The developed prototype is one of the main tools for the pilot. However, not all desired functionality can be tested with the prototype, which has its focus on selection and presentation. To incorporate also other aspects of the implementation of a 3D cadastre, mock-ups of possible functionality will be used; see Figure 7. This is in particular the case for the registration of 3D data. The spatial information is supplied by cadastral engineers. These engineers are not employed by Rosreestr and are private entities. The information is being validated by Rosreestr: is the geometry correct, are all required attributes present and other required checks. After the new information has been validated, the spatial information is approved and entered in the cadastral registration. After this, the legal information about ownership, encumbrances and other aspects are linked to the parcel(s). The outline of the workflow for registering new 3D objects is presented in the figures below. Figure 6 presents the overall workflow.

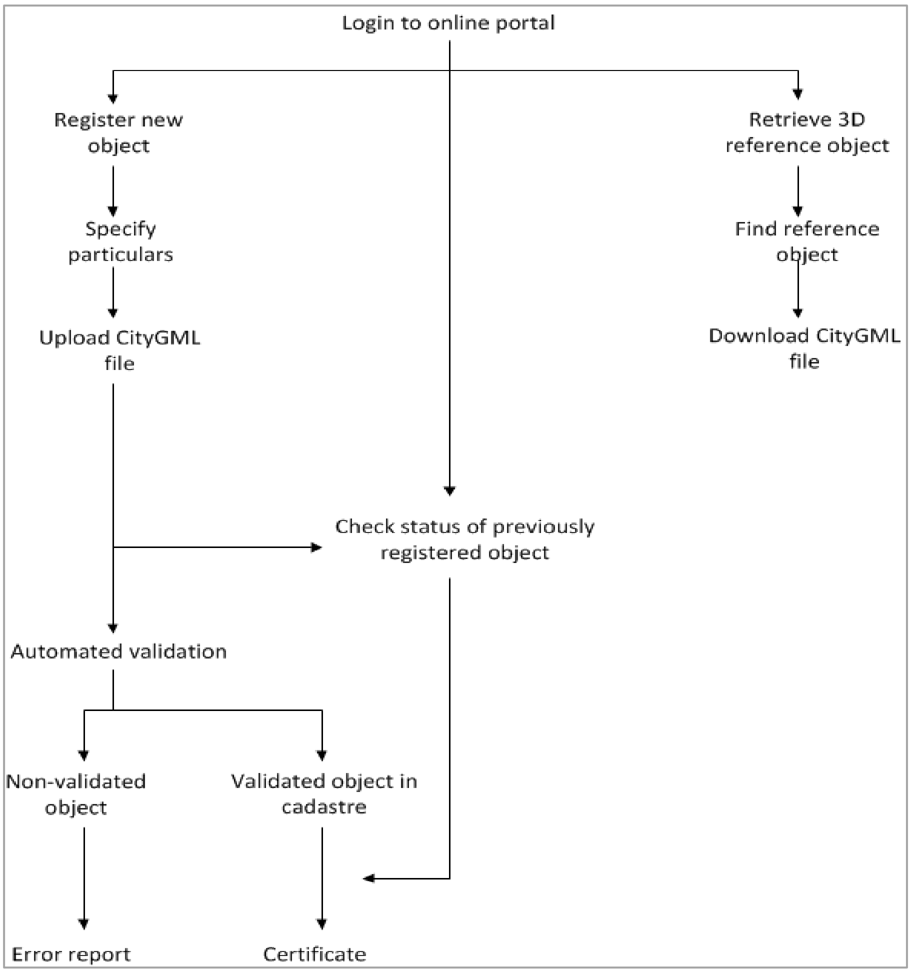

Figure 6. Overall workflow of the web-based registration of new Cadastral Objects

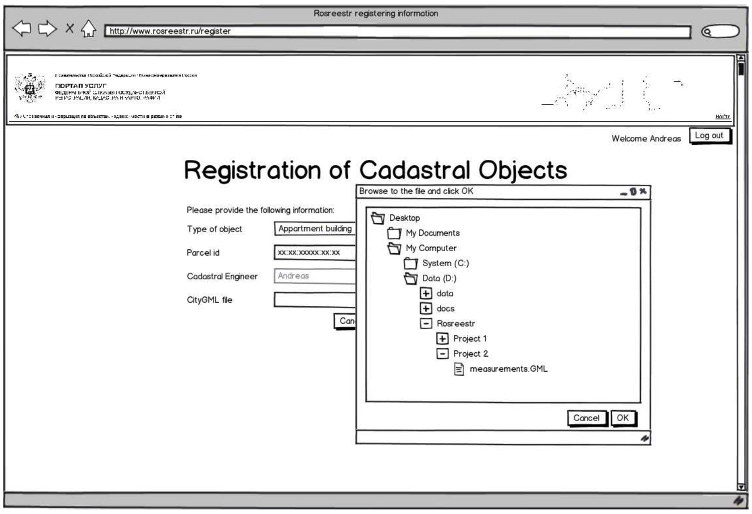

Figure 7. Mock-up of the web-based registration of new Cadastral Objects.

4. CONCLUSION

The aim of the "3D Cadastre Modelling in Russia" project, a cooperation by Russian and Dutch partners, is to create favourable (legal, institutional, and technical) conditions for the introduction of 3D cadastre in Russia. To gain experience a prototype has been developed for sample 3D cadastral objects from the pilot area Nizhegorodskaya Oblast. The experience and tools for proper description of 3D cadastral objects will be transferred to future data providers. It is important to realize that in the future the possible sources of 3D cadastral objects will originate from different sources than used in the prototype (however, this will not influence the workflow within Rosreestr):

- Direct survey in 3D (not tested in the current project);
- Start from existing floor plans and upgrade these to 3D volumes (as applied for the Nizhny Novgorod cases in the prototype, but processed more or less manually, while in the future more automation is possible);
- New buildings are often architecturally designed (CAD) directly in 3D, with limited additional effort (and clear guidelines) it should be possible to specify 3D cadastral objects for registration (this could be first tested; e.g. Skolkovo area).

The next step in the project is now to actually conduct actual pilot and based on the collected observations and experiences then update the guidelines with clear descriptions for the various 3D situations that occur in practice:

- What to do with wall or ceilings?
- What to do with disconnected (multi-part) 3D cadastral objects?
- What horizontal and vertical reference system to use (in what RF area)?
- What to do with pipelines crossing multiple parcels?
- What to do with curved surfaces (non-horizontal/vertical)?

- What to do with partial (un)bounded objects?
- When can 3D Cadastral Unit exist (specific rules or not; e.g. relation to construction or connection to Earth surface)?

The results of the pilot are multiple. This includes the gained knowledge within the project team concerning the technical, organisational and legal implications of an information system as it is implemented in the pilot area. Another important result is formed by the experiences of the stakeholders with the prototype and the better understanding of the benefits of a 3D Cadastre in Russia. Therefore, after a successful pilot, the next step is to apply the proposal for 'favourable legal and institutional conditions' to an operational real-world situation, but in a limited and controlled, environment; e.g. in the Skolkovo area. In the future, after the current project, the final step would be to build the production environment with more functionality: including a validator, DBMS data storage, on-the fly creation of the XML/X3D data stream from the database, and extend the 3D viewer to also show the neighbour units in 3D (check their mutual relationship; e.g. Teledom above shops). The validator should automatically check the 3D cadastral objects against the formal rules, before the new objects are accepted and stored in the DBMS. In the prototype this was difficult to built (and therefore omitted). However, in the production environment, proper data management tools can be used to implement some of the checks by using the correct geometric data type in the Oracle DBMS: a solid type. Also, checks for potential conflicts with other 3D objects (or columns implied by 2D surface parcel) can be implemented efficiently in this environment. Some of the tasks of the validator include:

- Check spatial aspects (flat faces, partition of space: no overlap or gaps, etc.);
- Check consistency between spatial – legal/admin data; and
- Check legal/admin attributes, proper transfer of rights between involved parties.

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BIOGRAPHICAL NOTES

Natalia Vandysheva holds a PhD in Physics and Mathematics from S.-Petersburg University, Russia. About 30 years experience in spatial data processing, digital mapping, GIS applications for land monitoring and cadastre. Since 2000 works as the head of the Spatial Data department in the Federal Cadastral Centre "Zemlya"("Land") being responsible for digital cartography and creation of cadastre information systems on the basis of GIS-technologies. Now is also involved in creation of SDI of the Russian Federation that are implemented under the direction of the Rosreestr (Federal Service for State Registration, Cadastre and Mapping). Project leader or expert in many international projects (USA, UNEP, EU countries).

Sergey Sapelnikov graduated from the Moscow State Technical University named after N. Bauman. Since 2009 works as the Deputy Head of the Federal Service for State Registration, Cadastre and Cartography. Area of his responsibility includes development of Spatial Data Infrastructure of the Russian Fedration, introduction of electronic services into registration of real property rights and keeping of cadastre, creation of the digital Public Cadastral Map, maintenance and improvement of mapping in the Russian Federation.

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