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An Experiment to Link Geo-Referenced Multimedia and CityGML Features

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Contents

Page

Abstract

In this paper, we present an experiment on linking geo-referenced images and videos with CityGML objects. Data models are proposed with XML schema from two viewpoints: one for linking features in 2D images or videos with 3D CityGML objects and the other for camera FoV (Field of View). In order to validate the proposed data models, we developed an authoring tool for building XML documents to link geo-referenced images and videos with CityGML objects and a web environment for processing queries based on the linking data.

Keywords

georeferenced images, georeferenced videos, FoV, Field of View, CityGML

An Experiment to Link Geo-referenced Multimedia with CityGML Objects

1 Introduction

1.1 Scope

The scope of this Discussion Paper covers a use-case for handling geo-referenced multimedia with CityGML 2.0. The geo-referenced multimedia that we discuss in the paper includes images and videos but excludes other types of multimedia such as audio or paintings. The Discussion Paper proposes an approach to handle such multimedia, but is not a proposal for a new standard. This OGC® document is applicable to those cases where multimedia with location data is used for data construction and integration of referenced multimedia.

1.2 Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

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1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
13/12/2019	1.0	Ki-Joune Li		Initial draft

2 References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC: OGC 12-019, *OGC® OGC City Geography Markup Language (CityGML) Encoding Standard*, 2012

OGC: OGC 18-075, *OGC® Moving Features Encoding Part I: XML Core*, 2019

In addition to this document, this report includes a XML Schema Document file as specified in Annex A.

3 Discussion Paper overview

This Discussion Paper presents an experiment on linking and integrating geo-referenced multimedia with CityGML. We first discuss the requirements for the data modeling of geo-referenced multimedia, which includes camera images and videos from two different viewpoints – Features in multimedia and Camera viewpoint. Based on the requirements, a UML data model and XML schema are designed for the implementation. In order to implement the data model and XML schema for the linking and integration, an environment for editing geo-referenced multimedia and query processing has been developed.

The rest of the Discussion Paper is organized as follows:

- the basic concepts, including the motivation of the use-case study and the requirements, in section 6;
- an UML class diagram with XML schema in section 7;
- implementation experiments, including editors and a query processing tool, in section 8; and
- the paper is concluded in section 9.

4 Basic Concepts

4.1 Background

Most photo images and videos are taken from the real world and include their acquisition time and location. These spatial and temporal properties are interpreted in two ways: the location and time where the images or videos have been taken and the geospatial features in the images or videos. First, the photos or videos have the spatial properties of the camera, which are defined as FoV (Field of View) [1] as illustrated in the right part of Figure 1. Second, an image or video may contain features, which exist in the real world and therefore can be represented as 3D city features in CityGML [2].

Through the 3D city features, these spatial properties allow the link of geo-referenced images and videos together with even cartoons or text that have no acquisition position. We may embed 3D city features in geo-referenced images and videos and vice-versa as requested by augmented reality systems. In the Discussion Paper, we discuss how to represent geo-referenced images and videos as well as geospatial features in images and video using CityGML.

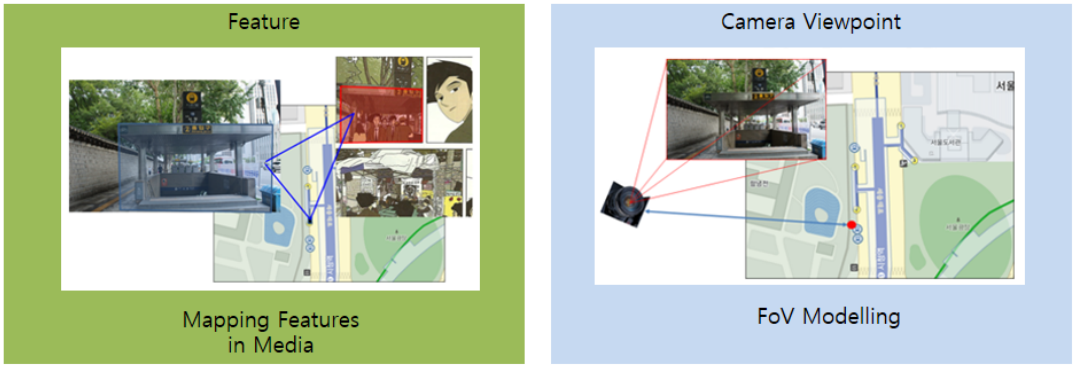

Figure 1– Linking geo-referenced images and videos

4.2 Requirements of data models for linking geo-referenced multimedia

We need a proper data model to represent the geospatial properties of images and videos, which are, in general, interpreted from two viewpoints as briefly addressed in section 4.1. First, the geospatial features in an image or video have to be represented.

- Each feature in an image or a video frame needs to be represented as a 2D spatial object by the screen coordinate reference system.
- This 2D spatial object is mapped to a 3D CityGML feature in the real world. This mapping may be implemented via GML identifier or coordinate transformation between the 2D screen Coordinate Reference System (CRS) and the 3D CRS of the real world.
- A video is defined as a sequence of video frames, each of which we consider as an image.

Second, the spatial properties of the camera location are defined as a *FoV* (Field of View) as shown in Figure 2. While each photo image has a FoV, a video has a sequence of FoVs if the camera is moving.

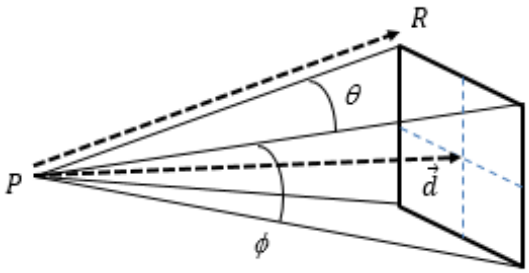

Figure 2 – FoV
p : Camera location (longitute, latitude, altitude)
ϕ, θ : vertical and horizontal angles
d: camera direction vector
R: visible distance

The requirements for the representation of geo-referenced image and videos are summarized as Figure 3.

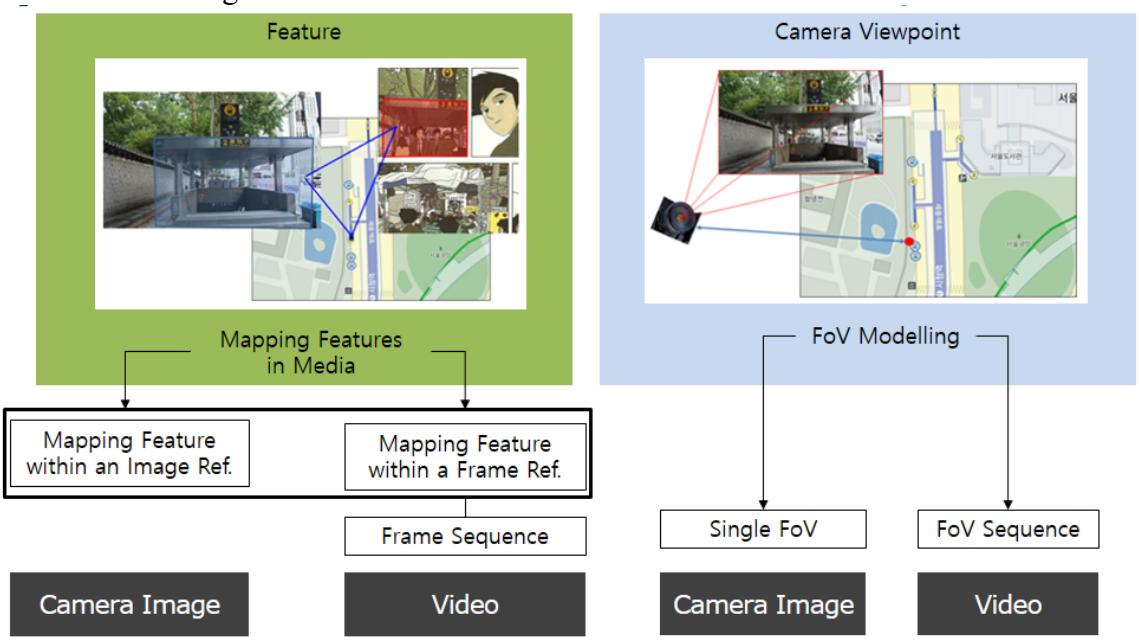

Figure 3 – Requirements for linking geo-reference mediaFoV

5 Data models and XML schema

In this section, we define the data model for geo-referenced image and video. The data model contains two packages, one for features in an image and video and the other for camera FoV. First the UML class diagram for geo-referenced features in image and video is given as Figure 4.

The key part of the first package shown in Figure 4 is the class for geo-referenced feature (GeoReferencedFeature) included in GeoReferencedImage or GeoReferencedFrame, where an instance of GeoReferencedVideo is a sequence of GeoReferencedFrame.

The second package for camera FoV is defined as Figure 5. It contains the class of 3D FoV for a photo image and a sequence of FoV for mobile camera. The properties of a FoV are explained in section 4.2.

The XSDs of these two packages are given in Annex A.

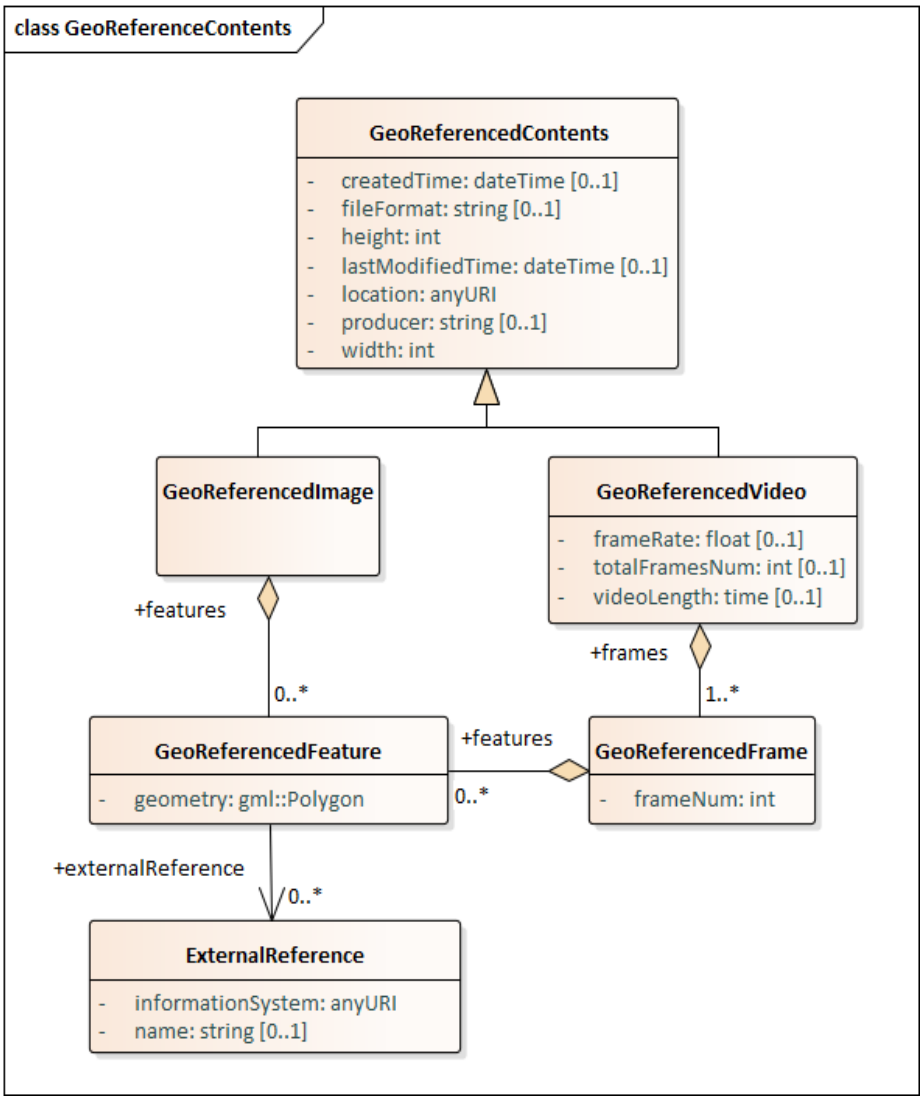

Figure 4 – UML class diagram for features in geo-referenced images and videos.

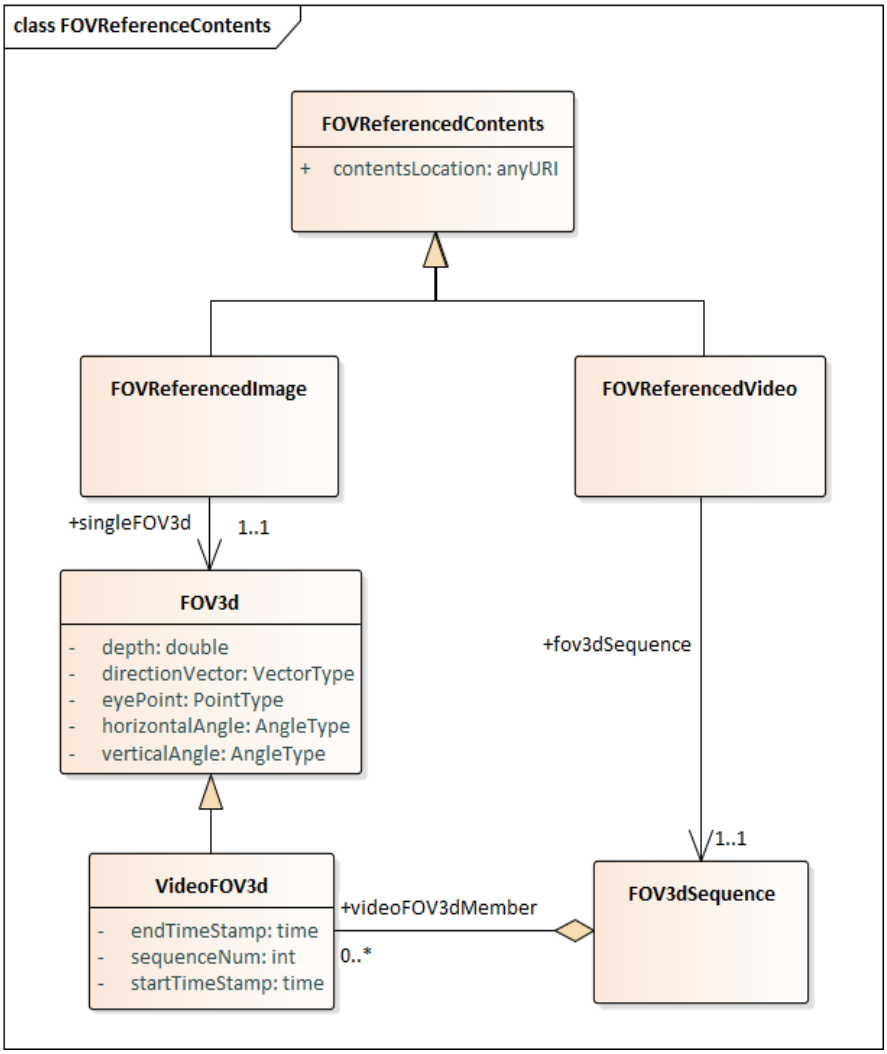

Figure 5 – UML class diagram for camera FoV

6 Implementation Experiments

In order to validate the data model and schema for geo-referenced image and video, we implemented an authoring tool and a web environment for query processing. This experiment does not intend to provide a service for real applications, but to prove the feasibility of linking geo-referenced images and videos. The first module provides an authoring tool for building XML data sets according to the XSD for geo-referenced images and videos. Use of the first module illustrates a procedure for constructing geo-referenced images and videos and highlights key challenges. With the second module, we experiment how to link geo-referenced images and videos.

6.1 Editing tool

In section 5, we discussed two data models for representing geo-referenced images and videos. An authoring tool was developed to assist building XML documents for the data models and XML schemas described in the previous section. This tool receives images and videos with EXIF data that include the camera position and additional data, which we need for FoV. This tool is web-based solution developed in javascript and node.js and its overall structure is shown in Figure 6.

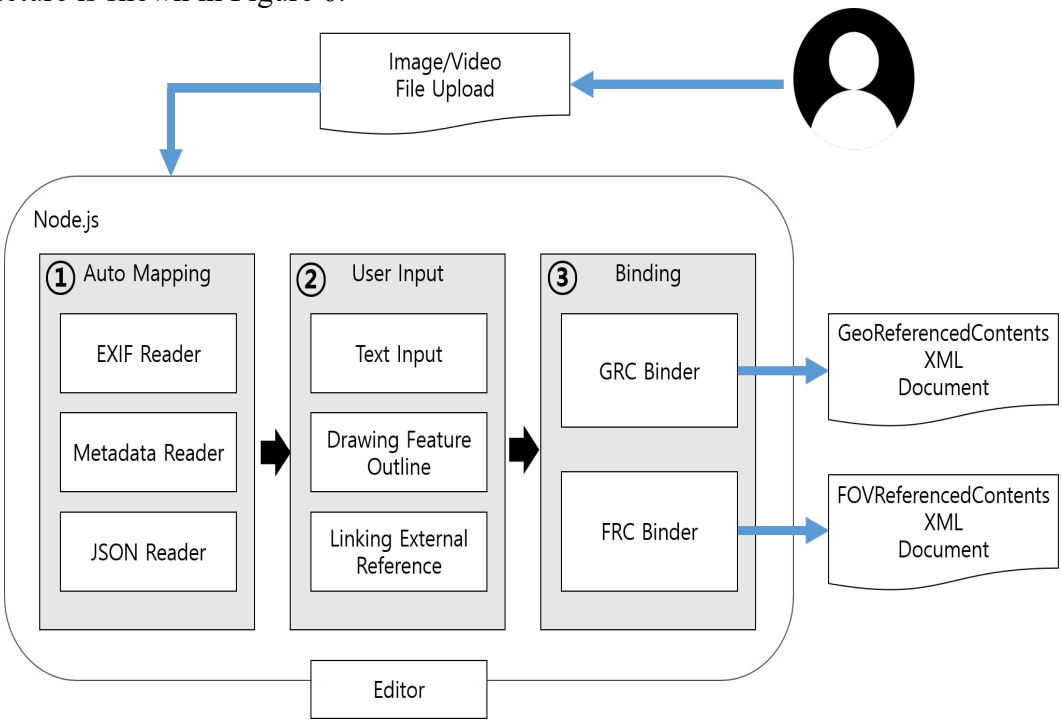

Figure 6 – System Architecture of the editor

This tool includes an editing environment for manual input of textual data, feature contour polygon in an image, and reference to the corresponding CityGML feature. It generates two different XML documents: one for features in a geo-referenced image or video and the other one for camera FoV, which are produced by two modules in Figure 6: GRC (Geo-Referenced Contents) binder and FRC (FoV-Referenced Contents) binder, respectively. Figure 7 shows a screen capture of the authoring tool.

6.2 Mapping CityGML objects into features in an image

As shown in Figure 6, the construction of XML documents for geo-referenced image and video includes a step to find 2D contour polygons of geospatial features of a 3D CityGML object. As the 3D geometry of the CityGML object and FoV are given, it is theoretically possible to transform each 3D CityGML object to the contour polygon in the screen CRS as shown in Figure 8.

Due to the low accuracy of GPS sensors and digital compass of the camera device in a smartphone, it is difficult to obtain an accurate contour polygon in the screen. As shown by Figure 9, we discover a serious discrepancy between the feature and corresponding contour polygon derived from CityGML feature.

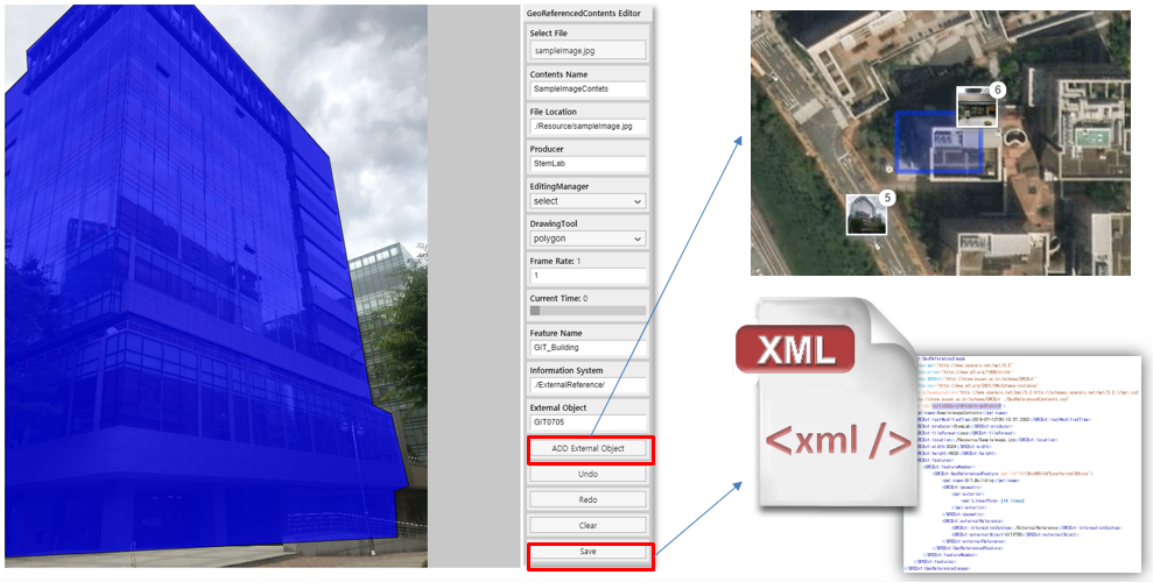

Figure 7 – A screen capture of the editor

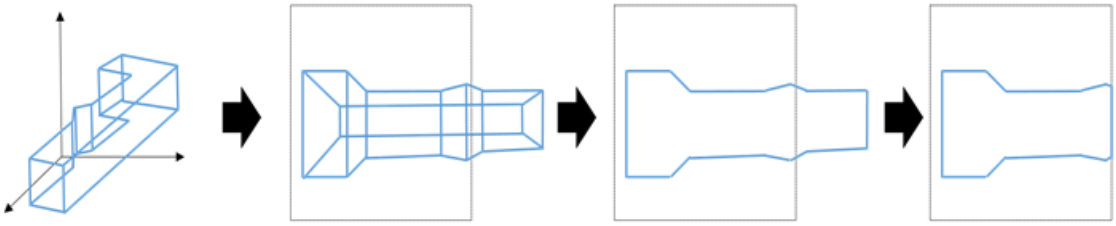

Figure 8 – Transforming 3D CityGML geometry to 2D polygon in screen

Figure 9 – An example of the mapping result

From this observation, we conclude that it is difficult to derive the contour polygon from 3D CityGML feature and therefore manual intervention is required by the authoring tool. We do not include in this paper the discussion on the image processing for extracting contour polygons from images.

6.3 Query Processing with geospatial properties in image and video

We developed a web environment to validate how to use geospatial data of images and videos given in XML documents for query processing. The queries are of two types as follows:

- Query type 1: Find a CityGML feature corresponding with the selected feature in an image; and
- Query type 2: Find images including the features selected in a 2D map.

The results of query processing are shown in Figure 10. The left part of the figure illustrates the query type 1. When we click a point in an image, the corresponding CityGML feature is found using the linking between 2D features in image and 3D CityGML features. The right part of the figure shows a building selected from a 2D map and four images whose FoV intersect with this building in the 2D map.

Figure 10 – An example of query processing

7 Conclusion

In this paper, we showed an experiment on how to link geo-referenced images and videos with CityGML features. The goal of the experiment is not to provide a service but to investigate the data modeling, building procedure of geo-referenced images and videos, and query processing. Future work may include:

- Automated extraction of contour polygons from images and mapping with CityGML features;
- Representation of mobile FoV in the OGC Moving Features standard; and
- Application of this approach for real services such as augmented reality.

Annex A

XML Schema for Geo-referenced Images and Videos

A.1 XML Schema for Features in Geo-Referenced Images and Videos

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema
    xmlns="http://stem.pusan.ac.kr/schema/GRCExt"
    targetNamespace="http://stem.pusan.ac.kr/schema/GRCExt"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    elementFormDefault="qualified" version="1.0.0">
    <!-- ========================================================================== -->
    <xs:import namespace="http://www.opengis.net/gml/3.2"
     schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
    <!-- ========================================================================== -->
    <xs:element name="GeoReferencedContents" type="GeoReferencedContentsType"
     substitutionGroup="gml:AbstractFeature"/>
    <!-- ========================================================================== -->
    <xs:complexType name="GeoReferencedContentsType">
        <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                <xs:sequence>
                    <xs:element name="createdTime" type="xs:dateTime" minOccurs="0"
                     maxOccurs="1"/>
                    <xs:element name="lastModifiedTime" type="xs:dateTime" minOccurs="0"
                     maxOccurs="1"/>
                    <xs:element name="producer" type="xs:string" minOccurs="0" maxOccurs="1"/>
                    <xs:element name="fileFormat" type="xs:string" minOccurs="0"
                     maxOccurs="1"/>
                    <xs:element name="location" type="xs:anyURI"/>
                    <xs:element name="width" type="xs:int"/>
                    <xs:element name="height" type="xs:int"/>
                </xs:sequence>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
    <!-- ========================================================================== -->
    <xs:element name="GeoReferencedImage" type="GeoReferencedImageType"
     substitutionGroup="GeoReferencedContents"/>
    <!-- ========================================================================== -->
    <xs:complexType name="GeoReferencedImageType">
        <xs:complexContent>
```



```
            <xs:extension base="GeoReferencedContentsType">
                <xs:sequence>
                    <xs:element name="features" type="GeoReferencedFeaturesType"
                     minOccurs="0" maxOccurs="1"/>
                </xs:sequence>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
    <!-- ========================================================================== -->
    <xs:element name="GeoReferencedVideo" type="GeoReferencedVideoType"
     substitutionGroup="GeoReferencedContents"/>
    <!-- ========================================================================== -->
    <xs:complexType name="GeoReferencedVideoType">
        <xs:complexContent>
            <xs:extension base="GeoReferencedContentsType">
                <xs:sequence>
                    <xs:element name="videoLength" type="xs:time" minOccurs="0"
                     maxOccurs="1"/>
                    <xs:element name="totalFramesNum" type="xs:int" minOccurs="0"
                     maxOccurs="1"/>
                    <xs:element name="frameRate" type="xs:float" minOccurs="0" maxOccurs="1"/>
                    <xs:element name="frames" type="GeoReferencedFramesType"/>
                </xs:sequence>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
    <!-- ========================================================================== -->
    <xs:complexType name="GeoReferencedFramesType">
        <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                <xs:sequence>
                    <xs:element name="frameMember" type="GeoReferencedFrameMemberType"
                     minOccurs="1" maxOccurs="unbounded"/>
                </xs:sequence>
                <xs:attributeGroup ref="gml:AggregationAttributeGroup"/>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
    <!-- ========================================================================== -->
    <xs:complexType name="GeoReferencedFrameMemberType">
        <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureMemberType">
                <xs:sequence>
                    <xs:element ref="GeoReferencedFrame"/>
                </xs:sequence>
                <xs:attributeGroup ref="gml:AssociationAttributeGroup"/>
            </xs:extension>
        </xs:complexContent>
```

```
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="GeoReferencedFrame" type="GeoReferencedFrameType"
 substitutionGroup="gml:AbstractFeature"/>
<!-- ========================================================================== -->
<xs:complexType name="GeoReferencedFrameType">
      <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                  <xs:sequence>
                        <xs:element name="frameNum" type="xs:int"/>
                        <xs:element name="features" type="GeoReferencedFeaturesType"
                         minOccurs="0" maxOccurs="1"/>
                  </xs:sequence>
            </xs:extension>
      </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:complexType name="GeoReferencedFeaturesType">
      <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                  <xs:sequence>
                        <xs:element name="featureMember"
                         type="GeoReferencedFeatureMemberType" minOccurs="0"
                         maxOccurs="unbounded"/>
                  </xs:sequence>
                  <xs:attributeGroup ref="gml:AggregationAttributeGroup"/>
            </xs:extension>
      </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:complexType name="GeoReferencedFeatureMemberType">
      <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureMemberType">
                  <xs:sequence>
                        <xs:element ref="GeoReferencedFeature"/>
                  </xs:sequence>
                  <xs:attributeGroup ref="gml:AssociationAttributeGroup"/>
            </xs:extension>
      </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="GeoReferencedFeature" type="GeoReferencedFeatureType"
 substitutionGroup="gml:AbstractFeature"/>
<!-- ========================================================================== -->
      <xs:complexType name="GeoReferencedFeatureType">
      <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                  <xs:sequence>
                        <xs:element name="geometry" type="gml:PolygonType"/>
```

```
                    <xs:element name="externalReference" type="ExternalReferenceType"
                     minOccurs="0" maxOccurs="unbounded"/>
                </xs:sequence>
            </xs:extension>
        </xs:complexContent>
    </xs:complexType>
    <!-- ========================================================================== -->
    <xs:complexType name="ExternalReferenceType">
        <xs:sequence>
            <xs:element name="informationSystem" type="xs:anyURI"/>
            <xs:element name="externalObject" type="xs:string" minOccurs="0" maxOccurs="1"/>
        </xs:sequence>
    </xs:complexType>
</xs:schema>
```

A.2 XML Schema for Camera FoV

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema
        xmlns="http://stem.pusan.ac.kr/schema/FRCExt"
        targetNamespace="http://stem.pusan.ac.kr/schema/FRCExt"
        xmlns:xs="http://www.w3.org/2001/XMLSchema"
        xmlns:gml="http://www.opengis.net/gml/3.2"
        xmlns:xlink="http://www.w3.org/1999/xlink"
        elementFormDefault="qualified" version="1.0.0">
        <!-- ========================================================================== -->
        <xs:import namespace="http://www.opengis.net/gml/3.2"
         schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
        <!-- ========================================================================== -->
        <xs:element name="FOVReferencedContents" type="FOVReferencedContentsType"
         substitutionGroup="gml:AbstractFeature"/>
        <!-- ========================================================================== -->
        <xs:complexType name="FOVReferencedContentsType">
         <xs:complexContent>
            <xs:extension base="gml:AbstractFeatureType">
                <xs:sequence>
                    <xs:element name="contentsLocation" type="xs:anyURI" minOccurs="0"
                     maxOccurs="1"/>
                </xs:sequence>
            </xs:extension>
         </xs:complexContent>
        </xs:complexType>
        <!-- ========================================================================== -->
        <xs:element name="FOVReferencedImage" type="FOVReferencedImageType"
         substitutionGroup="FOVReferencedContents"/>
        <!-- ========================================================================== -->
        <xs:complexType name="FOVReferencedImageType">
         <xs:complexContent>
```

```
        <xs:extension base="FOVReferencedContentsType">
            <xs:sequence>
                <xs:element name="singleFOV3d" type="FOV3dPropertyType"/>
            </xs:sequence>
        </xs:extension>
 </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="FOV3d" type="FOV3dType" substitutionGroup="gml:AbstractFeature"/>
<!-- ========================================================================== -->
<xs:complexType name="FOV3dPropertyType">
 <xs:sequence minOccurs="0">
        <xs:element ref="FOV3d"/>
 </xs:sequence>
 <xs:attributeGroup ref="gml:AssociationAttributeGroup"/>
</xs:complexType>
<!-- ========================================================================== -->
 <xs:complexType name="FOV3dType">
 <xs:complexContent>
        <xs:extension base="gml:AbstractFeatureType">
            <xs:sequence>
                <xs:element name="eyePoint" type="gml:PointType" minOccurs="0"
                 maxOccurs="1"/>
                <xs:element name="horizontalAngle" type="gml:AngleType" minOccurs="0"
                 maxOccurs="1"/>
                <xs:element name="verticalAngle" type="gml:AngleType" minOccurs="0"
                 maxOccurs="1"/>
                <xs:element name="directionVector" type="gml:VectorType" minOccurs="0"
                 maxOccurs="1"/>
                <xs:element name="depth" type="xs:double" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
        </xs:extension>
 </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="FOVReferencedVideo" type="FOVReferencedVideoType"
 substitutionGroup="FOVReferencedContents"/>
<!-- ========================================================================== -->
<xs:complexType name="FOVReferencedVideoType">
 <xs:complexContent>
        <xs:extension base="FOVReferencedContentsType">
            <xs:sequence>
                <xs:element name="fov3dSequence" type="FOV3dSequencePropertyType"/>
            </xs:sequence>
        </xs:extension>
 </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="FOV3dSequence" type="FOV3dSequenceType"
```



```
 substitutionGroup="gml:AbstractFeature"/>
<!-- ========================================================================== -->
<xs:complexType name="FOV3dSequencePropertyType">
 <xs:sequence minOccurs="0">
      <xs:element ref="FOV3dSequence"/>
 </xs:sequence>
 <xs:attributeGroup ref="gml:AssociationAttributeGroup"/>
</xs:complexType>
<!-- ========================================================================== -->
<xs:complexType name="FOV3dSequenceType">
 <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureType">
           <xs:sequence>
                <xs:element name="videoFOV3dMember" type="VideoFOV3dMemberType"
                 minOccurs="0" maxOccurs="unbounded"/>
           </xs:sequence>
      </xs:extension>
 </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:complexType name="VideoFOV3dMemberType">
 <xs:complexContent>
      <xs:extension base="gml:AbstractFeatureMemberType">
           <xs:sequence minOccurs="0">
                <xs:element ref="VideoFOV3d"/>
           </xs:sequence>
           <xs:attributeGroup ref="gml:AssociationAttributeGroup"/>
      </xs:extension>
 </xs:complexContent>
</xs:complexType>
<!-- ========================================================================== -->
<xs:element name="VideoFOV3d" type="VideoFOV3dType" substitutionGroup="FOV3d"/>
<!-- ========================================================================== -->
 <xs:complexType name="VideoFOV3dType">
 <xs:complexContent>
      <xs:extension base="FOV3dType">
           <xs:sequence>
                <xs:element name="sequenceNum" type="xs:int"/>
                <xs:element name="startTimeStamp" type="xs:time"/>
                <xs:element name="endTimeStamp" type="xs:time"/>
           </xs:sequence>
           <xs:attributeGroup ref="gml:AggregationAttributeGroup"/>
      </xs:extension>
 </xs:complexContent>
</xs:complexType>
</xs:schema>
```

Bibliography

[1] Polys, Nicholas F., Seonho Kim, and Doug A. Bowman. "Effects of information layout, screen size, and field of view on user performance in information-rich virtual environments." *Computer Animation and Virtual Worlds* 18.1 (2007): 19-38.

[2] OGC 12-019, OGC® OGC *City Geography Markup Language (CityGML) Encoding Standard* , https://www.opengeospatial.org/standards/citygml

