THE UPDATING PROCESS FOR 3D CITY MODEL OBJECTS – AN OVERVIEW

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Key words: 3D City Models, Data Updating, 3D Change Detection, CityGML

SUMMARY

In spatial information system, the semantics attached to a land parcel is as important as it spatial counterpart. The similar concept is adopted by the 3D city model standard and data model, known as CityGML. It has been accepted by the Open Geospatial Consortium (OGC) as one of the international standards for 3D city models that is able to represent the geometry, topology and appearance of 3D city models in five Level-of-Details (LoD), namely LoD0 to LoD4. Apart from the spatial features, CityGML also emphasized on the importance of spatio-semantic coherent model as every spatial feature in each 3D city model object should be accompanied by its corresponding semantic information to ensure that the model is spatially and semantically correct. The process of generating 3D city models has been greatly improved with the availability of sophisticated tools such as Lidar, terrestrial laser scanning equipments and high resolution cameras where the 3D data obtained and generated are more accurate and cost-effective. However, the task of updating the data is still a major predicament in 3D city model. While it is easier to replace the whole current 3D city models with the newly generated ones, the action will result in the loss of valuable data. This paper attempts to introduce a method that could improve the 3D city models updating process by implementing a selective updating where 3D buildings will be updated based on the changes on its geometries or semantics. The proposed method utilizes a hybrid 3D segmentation method that based on semantic and geometric decomposition for 3D buildings in order to detect and pinpoint the location of any changed structures. Based on the change detection results, the method will selectively determine the segmented geometries and semantics that will be updated on the geospatial database of the 3D city model. For future work, the proposed method will be extended for automatic features extraction from un-interpreted 3D models.

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1. INTRODUCTION

Urban developments are happening in rapid manner as the world moving forward in modernization. As a result, spatial entities especially man-made structures (buildings) are becoming more complex and ultimately render the 2D map insufficient in representing city objects. The need to have accurate digital representation of cities and urban areas for various purposes has led to the development of 3D city model. The worldwide popularity and involvement of various sectors has made 3D city modelling a trend in geospatial applications. Since its inception, the use of 3D city models has been expanded beyond visualization purposes where more disciplines and applications utilizing it for various analyses such as noise mapping (Kolbe, 2009), navigational tool and network analysis.

Urban entities such as buildings will experience some changes throughout the time. Furthermore, the progression in human civilization means there will always be new developments, constructions and renovations happening all around the city. A 3D city model should reflect the real situation of a city, thus, any development activities will affect the 3D building models. This triggered the need for the 3D building models to be updated to ensure that the information is relevant for future analysis.

The updating process for 3D buildings can be improved rather than replacing the whole data, by implementing selective updating process which deals with change detection method based on 3D segmentation. Change detection is usually describes as a way to monitor and keep track of changes that occur on geographic features or objects on the ground for various purposes such as 3D cadastre, urban planning, environment management and intelligence gathering. Its goal is to detect changes on geographic features by comparing multi-temporal data, identify the type of change and determine the amount of change (Im and Jensen, 2005). Currently, most of the change detection is done through spectral analysis of multi-temporal aerial or high resolution satellite images (Chen et. al, 2010) meanwhile in some cases, the images are used together with other data source such as DTM and LIDAR. The results from the change detection are vital in order for the proposed method to accurately update the 3D city models.

This paper mainly focuses on the selective updating for 3D city model objects (3D buildings) based on 3D change detection. In Section 2, this paper will discuss about past researches related to CityGML and 3D city models, the building generation methods, and 3D segmentations. Meanwhile, Section 3 will discuss the segmentation technique for 3D city models, the change detection process and the selection method for 3D city model data updating process. The last section will discuss the future work and conclusion that can be drawn from this paper.

2. RELATED WORKS

2.1 3D City Models and CityGML

CityGML is a data model to represent and exchange spatial data i.e. 3D city models, especially urban objects. According to Kolbe (2009), Groger and Plumer (2012), CityGML is in XML-based format and an application schema for the Geography Markup Language version 3.1.1 (GML3). The Open Geospatial Consortium (OGC) has accepted CityGML specifications as one of the international standards for representing and exchanging spatial data, along with GML3. CityGML able to represents the semantics, geometry, topology and appearance of 3D city models in five well-defined Level-of-Details (LoD), namely the LoD0 to LoD4. The accuracy and structural complexity of the 3D objects increases with the LoD level where LoD0 is the simplest LoD (2.5D Digital Terrain Model (DTM)) while LoD4 is the most complex LoD (architectural details with interior structures). Kolbe (2009) discussed in detail about the role of CityGML in exchanging and representing 3D city models, the aim of CityGML development, its modelling aspects, recent applications and its relation to other 3D standards such as IFC and KML.

Previously, 3D city models have been used mainly for visualization purposes but with the rapid development in 3D city modelling has prompted some applications such as facilities management, building information model and simulations to utilize additional information about the city objects with standardized representations as suggested by Kolbe (2009). Meanwhile, Groger and Plumer (2012) elaborated on the current development in CityGML, its features being the interoperable semantic 3D city model and current researches that aim to enhance the format for geospatial purposes. They provided several key points that differentiate CityGML with other graphically-focused format such as KML and X3D. Kolbe (2009), Groger and Plumer (2012) also stated the importance of semantic information supported in CityGML which is crucial in geospatial applications. In explaining the semantic aspect supported in CityGML, Groger and Plumer (2012) had provided UML diagrams that shows hierarchical structures of the semantic information for every LoDs which emphasized that coherent semantical-geometrical modelling is a very important aspect in CityGML.

2.2 3D Buildings Generation

The emergence of better hardware and software in the computer-related industries makes it easier for the users to generate 3D buildings. Some researchers even focused on the developing an automated process for generating 3D city models (Takase et. al, (2003), Sugihara and Hayashi (2008) and Steinhage et. al (2010). 3D building generation process is important in change detection and analysis since it will provide the input for the applications.

Isikdag and Zlatanova (2010) introduced an approach to draw and visualize simple geometric representation of 3D buildings directly in the Google Earth environment. Urban planning is known to be a complex and tedious process which involves many parties and joint decision making. They suggested that by introducing this approach, all parties involved can easily access and view the data, and get the better picture on the proposed structures and how it relates to the environment on the actual site rather than just looking at the architectural model while lacking on the information of the surrounding area.

Kim et. al (2008) presented a method to automatically generate Digital Building Models (DBM) with complex structures (parts with different slopes, sizes, and shapes) from LiDAR point clouds. The method consists of four steps. First, the ground/non-ground points are classified based on the visibility analysis among ground and non-ground points in a synthesized perspective view. Then, the non-ground points are analyzed and used to generate hypotheses of building instances based on the point attributes and the spatial relationships among the points. Next, each building is segmented into a group of planar patches. The intermediate boundaries for segmented clusters are produced by using a modified convex hull algorithm. These boundaries are used as initial approximations of the planar surfaces comprising the building model of a given hypothesis. Finally, those initial boundaries are used to derive a refined set of boundaries, which are connected to produce a wireframe representing the DBM.

2.2 Change Detection Methods

Bouziani et. al. (2010) proposed a new method to detect changes on buildings in urban environment based on very high spatial resolution images (VHSR) and existing geodatabase. In this research, a geodatabase on the buildings and other urban objects are developed and the parameters for the change detection are defined. Then, the VHSR image is segmented based on the segmentation parameters that have been computed. The segmented image is analyzed using geodatabase in order to localize the segments where the change of building is likely to occur.

Even though this research work was done in 2D, it provides some insights on how changes on a 3D building can be analysed accurately by segmenting the models. Figure 1 shows the result of the change detection where the newly detected buildings are in grey and the old buildings are in black. Meanwhile, Table 1 shows the number of buildings detected.

Fig. 1 Change detection result for the Quickbird image**.**

Table 1. Change detection result.

	Reference buildings	Buildings detected	Buildings not detected	False alarms
Subset 1— Ikonos 2006	89	82	7	8
Subset 2— QuickBird 2006	121	114	7	12

Chen et. al (2010) conducted a research to detect changes on building models from aerial images and LIDAR data. They start with registering multi-source data, namely the LIDAR data, aerial images and 3D building models. The image coordinate system is used as reference for the planimetric registration meanwhile the LIDAR coordinate system is used as reference for elevation registration. Next, they perform the change detection on the existing 3D building models by examining several features such as the spectrum from aerial images, height difference between building models and LIDAR points, and linear features from aerial images.

However, since the examination is based on linear features from aerial images and height difference from LIDAR data, this approach seems to be working only for simple structures. This limitation has a major impact on the change detection process for 3D buildings since most of the modern buildings out there are considered as complex structures.

2.3 3D Segmentation Methods

2.3.1 Overview

Segmentation is basically a method to break down an object into simpler parts for application-specific objectives. The development in 3D GIS has triggered the needs to use the tool for geospatial-related applications (You et. al, 2003; Hu et. al, 2004; Thiemann and Sester, 2004). According to Agathos et. al (2007) and Shamir (2008), there are two principal types of segmentation; namely surface-type and part-type The surface-type segmentation breaks down the mesh based on surface attributes to create distinct surface regions. Meanwhile, the part-type segmentation (also known as semantic-type) creates sub-parts by partitioning the mesh into meaningful or semantic components. Figure 2 shows the example of the part-type and surface-type segmentations.

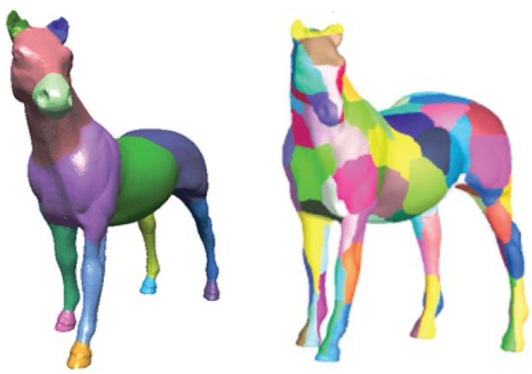


Fig 2. Results for Part-Type (Left) and Surface-Type (Right) Segmentations (Shamir, 2008)

2.2.2 3D Segmentation on 3D Buildings

3D model segmentation method has been used in various fields such as medical technology, computer vision and geospatial applications. However, it serves the same purpose which is to break down an object into simpler parts to be manipulated for different applications such as object analysis, feature extraction and classification, object recognition, model reconstruction and generalization. Although most of the segmentation method used in geospatial and building-related applications are based on 2D segmentation (Mian et. al (2006); Tolt et. al (2006); Miliaresis and Kokkas (2007); Sampath and Shan (2010); Cheng et. al (2010)), there are some researches that dwelled into the 3D segmentation as presented by You et. al (2002), Hu et. al (2004), Thiemann and Sester (2004), Poupeau and Bonin (2006) and, Manferdini and Remondino (2010).

Thiemann and Sester (2004) presented a research on segmentation of 3D building for generalization that utilized an adaptation of algorithm by Ribelles et. al (2001). Ribelles proposed a segmentation process that will detect holes, bumps and notches on a 3D building model by segmenting the model with one or more planes of its boundary.

Considering the algorithm as time consuming and self-imposed of high complexity, Thiemann and Sester (2004) introduced an extension from the original algorithm based on the theory that reducing the number of Boolean operation will reduce the complexity of the algorithm and its processing time. One split-plane is used and only if it yields no result then more split-planes will be used. In order to balance out the separation of bad protrusion features before the good complex hole, they also introduced a heuristics where only parts with value smaller than 1 are considered as valid. Figure 3 shows the segmentation on a building with 34 different split-planes.

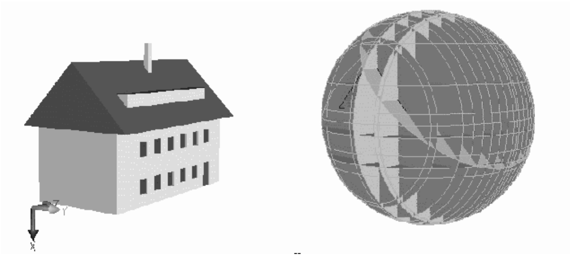


Fig 3. Segmentation of a sample building with 34 split-planes (Thiemann and Sester, 2004).

In other research, You et. al (2003) presented a methodology which indirectly support the proposed method for this research, that, fitting primitives can be used for both; modelling or partitioning 3D buildings. In You et. al (2003), several buildings are automatically modelled from LiDAR data by using the estimation of primitives fitting. Several basic primitives that are often used in building designs (i.e. planes, cylinders, spheres) are fitted to the LiDAR data through surface and edge fitting. The method also supports high-order modelling primitives (i.e. ellipsoids and superquadrics) for irregular building structures. Figure 4 shows an example of a quite complex building that made up from several basic primitives.

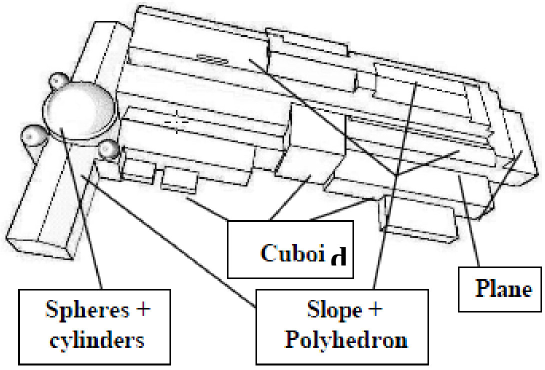


Fig 4. Example of building made up from several primitive (You et. al, 2002).

3. THE OVERVIEW ON THE SELECTIVE UPDATING METHOD FOR 3D CITY MODELS BASED ON CHANGE DETECTION RESULT

Over the years, there are lots of different approaches related to change detection for buildings that have been introduced. However, most of the methods mainly focused on the number of changed buildings that are successfully detected and in the end, they will replace the entire buildings, without analysing the changes that occurred on each building. This action resulted in some valuable information for building management and information systems are being discarded.

3.1 Segmenting the 3D Model Based On Geometric-Semantic Decomposition

The 3D city model objects (3D buildings) will be segmented using the hybrid segmentation technique (Sharkawi and Abdul-Rahman (2013)); based on part-type (often known as semantic) and surface-type elements where the segmentation result will not only be based on fitting primitives, but also based on their semantic properties. This technique is able to segment a 3D model directly in vector data format, making the result have a higher accuracy than segmenting a raster data. To summarize the geometric segmentation process, each face will be decomposed into primitive shapes based on the orthogonal projections of vertices onto parallel edges.

Semantic decomposition will group the 3D building's geometries based on its attribute values, which is important in order to preserve the existing semantic information for the data comparison process. The semantic data can be provided together in the CityGML file of the 3D building. Figure 5 shows a CityGML file that contains semantic data of the building.

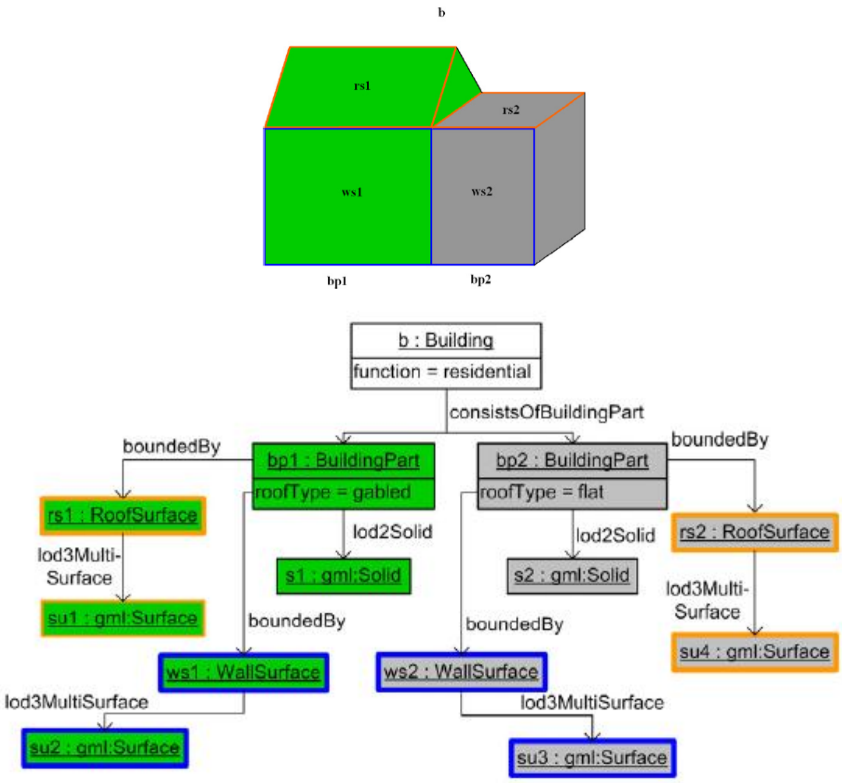
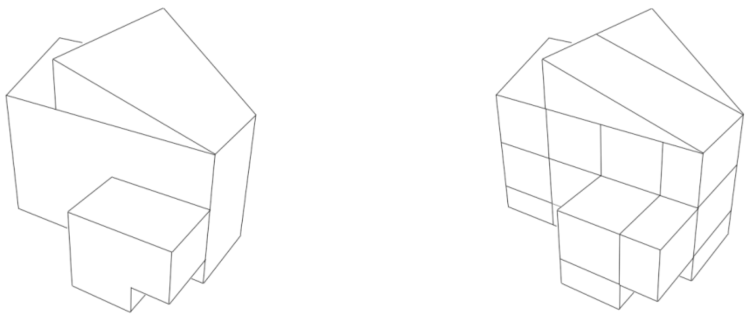


Fig. 5. Semantic attributes in CityGML file (Groger and Plumer, 2012).

Meanwhile, the geometric segmentation will further partitioned the parent geometries into smaller and simpler parts, The geometric segmentation will decompose the complex polygons into simpler parts or primitive shapes (as shown in Figure 6).



a) Original building b) Segmented model

Fig 6. The results of the segmentation process

3.2 Updating the 3D City Models Using Selective Method Based On 3D Change Detection

The segmented model contains a number of segments based on a group of primitive shapes or in other words, is a combination of primitive shapes that makes up the whole building. The segmented parts will allow the changes to be located on the building structures. The comparison for the semantic information is done by determining whether there is any changes occurred between the 2 datasets. If there are any discrepancies, the semantic information will be marked for the selection process later on. Meanwhile, the segmented parts will be marked as changed structures if there is any difference between the 2 datasets. The flow of activities for the updating process is shown in Figure 7.

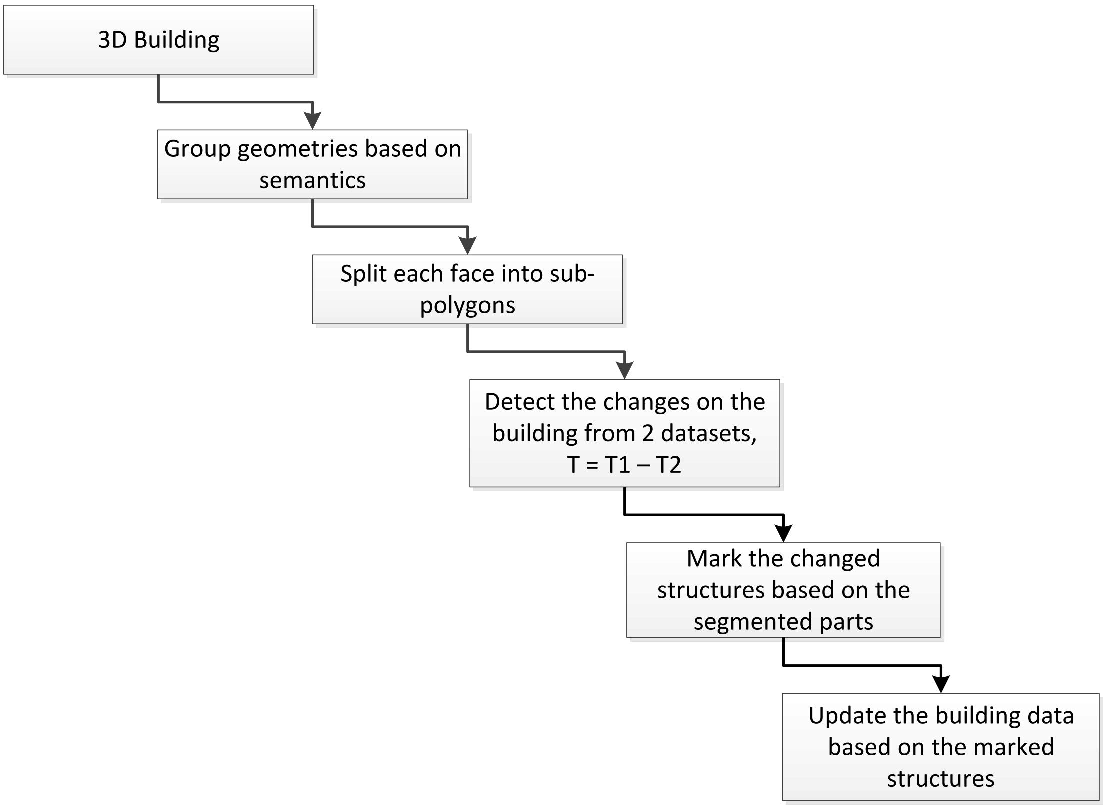


Fig 7. The flow of activities for the updating process

The selection process allows the proposed method to determine and update only eligible data instead of replacing the whole 3D city models. It will ensure the quality of the updated data and avoid unnecessary updating process. The method also able to enhance the semantic information based on the segmented parts and pin-point the changes that occurred on a building.

If a segmented part of the 3D building is determined as changed regardless the dataset sequence (current or new), the method will accept the segmented part in the new dataset as it assume that new dataset is always accurate. However, with the availability of additional parameters, the selected segments can be classified as demolished, renovated or new structure. The changes on the segmented parts are also affecting the semantic selection process. For example, if a segmented part is only available in one of the datasets, the method will immediately select the information from the new dataset.

Assuming the semantic information (and its geometric counterpart) in both datasets is available and not null, the selection process for the semantics is done by accepting the semantic information from the new dataset as it always consider the new datasets to contain the latest data. In the event of a null value is present in one of the dataset, the available information in any dataset will be accepted regardless its sequence. This is done based on the assumption that non-null value is better than null value. Figure 8 shows the change detection between the current and the new datasets and the selective data updating process.

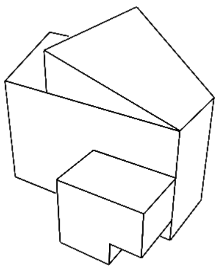
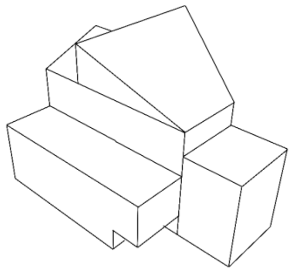
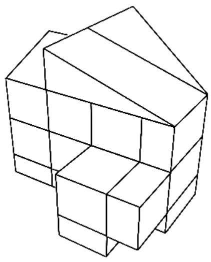
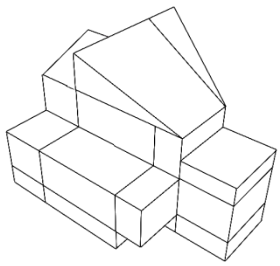
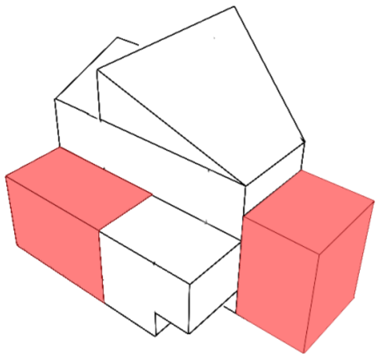
	Current Data	New Data
Original Building		
Segmented Building		
Selected Data For Updating Process (Shaded)		

Fig 8. The selective updating process

4. CONCLUSIONS AND FUTURE WORK

3D city model has gained a lot of interest in recent years. A number of research works attempt to enhance the usability of 3D city models in 3D analyses, instead of only for visualization purposes. This propelled the 3D city models as an important element in 3D geospatial applications in assisting the urban planners, local authorities and building managers. Updating a 3D city model can be a daunting and inefficient task for system operators. Replacing the whole model is proven to be easier but the action will caused important and valuable data to be discarded or loss. The proposed method described in this paper should be able to accurately update the 3D building based on the changes that occurred in its geometric and semantic information, instead of replacing the whole model which might include unnecessary updates for unchanged data. The segmentation by semantics will enable users to add specialized semantic information on the building parts in post-modelling stage while geometrical segmentation allow building parts to be defined. The results from the segmentation process are then used for detecting changes by comparing two sequential datasets (current and new datasets) and the changes on the semantic and geometric information will be marked and grouped for the selection process. The selection process will allow the method to correctly determine the data that is truly eligible for updating.

For future work, the proposed method could be extended for feature detections and extractions from un-interpreted models.

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