Goals and requirements of European National Mapping Organisations for change detection

Findings of the EuroSDR Working Group on Common goals and requirements for NMAs in change detection

1. Summary

The working group has made the following findings:

There continues to be an absence of automatic change detection solutions that are considered effective for use by National Mapping Organisations (NMOs).

NMOs consider that the features being mapped and the amount of change that has occurred are the most important factors for prioritising change detection (section 5).

Automatic change detection solutions that identify regions that have (or have not) changed or that alert to individual features that have changed are of most interest to NMOs (section 6).

Most NMOs have access to stereo aerial imagery and digital surface models and so would not incur additional data costs if they were to implement solutions using such data sources. However, NMOs are also interested to know if other data sources would give a better change detection solution (section 7).

The types of mapping that NMOs would most expect to update using automatic change detection and remotely sensed data are (section 9):

- topographic
- land-cover
- terrain height (e.g. DTM)
- natural variables (e.g. DSM, tree density or canopy height)

Potentially the most beneficial automatic change detection solution for National Mapping Organisations would compare a current source data set to topographic or land-cover mapping. This is possibly the most challenging of all change detection problems (section 8).

NMOs are generally interested in the following mapped features (section 10):

- Building features
- Road features
- Terrain features
- Waterbody features
- Vegetation features

Automatic change detection solutions would need to allow individual NMOs to set parameters in at least these three types of information (section 12):

- feature description
- change amount
- change confidence

We propose a test of change detection solutions against sets of data compiled under the following topic areas (section 11 and Appendix B):

- Terrain and surface model
- Buildings and roads
- Vegetation areas
- Waterbody

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2. Authors

This paper details the outcomes of the first phase of the EuroSDR Working Group on "Common goals and requirements for the NMAs in change detection". The working group was set up in November 2010 following the success of EuroSDR Workshop on "Automated change detection for updating national databases" in March 2010 (EuroSDR Workshop, 2010). The working group held 2 workshops and used the results of 2 questionnaires as well as online discussion to arrive at the presented findings.

2.1. Working group members

The working group comprised the following members:

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3. Introduction

This document is intended to set out the goals and requirements of European National and Regional Mapping Organisations for change detection. It has been written by a working group set up within EuroSDR and is based on information obtained through workshops, surveys and online collaboration.

The purpose of the document is to enable researchers and designers of change detection software to understand what are the most important aspects of the change detection problem so that those researchers/designers can focus on these aspects when developing change detection solutions. The document sets out what National Mapping Organisations understand by change detection and briefly outlines how change detection is currently undertaken in National Mapping Organisations (The change detection problem, section 4). What is most important to a National Mapping Organisation can depend on a number of factors and so we give an overview of how priorities are set across the region represented by our working group (Setting priorities, section 5).

Greater detail is then given by identifying the most important factors within the problem of change detection for National Mapping Organisations across the region. The data used to identify change is described in Change detection source data (section 7), and how it would be used is described in Change detection method (section 8). Detail about those mapping products that would be expected to be updated following change detection is given in Mapping products (section 9) and further descriptions of the real-world features on which change detection should focus are given in Mapping features (section 10). Finally, we provide recommendations for topic areas on which automatic change detection research should focus (Automatic change detection topic areas, section 11).

What is not covered by this document are the criteria for accuracy. For instance, many National Mapping Organisations strive for the highest quality of mapping and have stated that they would wish for completeness (the percentage of real-world changes of interest that are detected) of 80-90% and correctness (the percentage of detected changes which are real-world changes of interest) of >80% (Change detection questionnaire 1, 2010). These may be unrealistic aims and may vary given factors such as the political climate and technological capability.

It would be more valuable to see what solutions can achieve within a rigorous test such as that proposed in Appendix B: Next steps. This document also doesn't set out the cost constraints of National Mapping Organisations, largely because these are unknown and also change over time.

Throughout the document, the term National Mapping Organisation is used to identify bodies charged with mapping large regions. These are usually government bodies who map entire countries but can also include federal agencies and private companies with responsibility to national government. A glossary gives definitions for other terms used in this document.

4. Glossary

A number of terms are used in this report. Below is a table of meaning that the working group ascribe to these terms.

Term	Definition
Actuality	In the case of mapping, this term is used to mean up-to-dateness or currency.
Address data	Data giving the geographic location of addresses (e.g. postal addresses).
Breakline	In TIN or point terrain height data, breaklines are used to preserve the shape of the model where this is important. For example, they may define the shape of a break in slope that is not well modelled by the TIN or points.
Cadastral mapping	Mapping that represents the boundaries of land ownership.
Coverage	A type of 2-dimensional mapping in which every possible location can have a value. Examples include terrain height, biomass and vegetation density maps.
Dense Point Matching	One of the many terms used to describe the derivation of digital surface models by matching points (and other features) between many overlapping images. Also known as multi-ray photogrammetry, image matching, dense matching and dense image point matching.
Digital Surface Model	In this work, we consider that a digital surface model is raster, grid, TIN or point data that describes the height of the Earth's surface including all objects on it (e.g. the top of buildings, bridges, trees, etc.).
Digital Terrain Model	In this work, we consider that a digital terrain model is raster, grid, TIN or point data that describes the bare ground surface of the Earth with all objects (e.g. buildings, bridges, trees, etc) removed.
DSM	See Digital Surface Model
DTM	See Digital Terrain Model
EuroSDR	A not-for-profit organisation linking National Mapping and Cadastral agencies with Research Institutes and Universities for the purpose of applied research in spatial data provision, management and delivery. http://www.eurosdr.net
Ikonos	Commercial satellite launched in 1999 collects panchromatic images with 82-centimeter resolution and multispectral imagery with 4-meter resolution. http://www.geoeye.com/CorpSite/products-and-services/imagery-sources
Illumination angle	The angle between the normal to the illuminated surface and the direction of light.
Image Matching	see Dense Point Matching
Land cover mapping	The physical cover of the Earth, usually represented as a set of classes. At the very least, these classes would be 'vegetation', 'water', 'man-made material' and 'unvegetated natural surface'.
Land use mapping	The use to which a tract of land is put, usually represented as a set of classes such as 'recreation', 'industry', 'agriculture'.
Laserscanning	The use of laser beams to measure distance from the laser scanner. From this, models of surface shape and height can be built.
Lidar	See Laserscanning
Object-based mapping	Mapping in which real-world features (e.g. buildings, waterbodies, urban regions) are defined as objects.

Term	Definition
Orthorectification	The process of aligning imagery to the co-ordinate system and removing distortion. This requires information about terrain relief, lens distortion and camera view position and angle.
Panchromatic imagery	Greyscale imagery that for which the light measurement is across all (or most) visible wavelengths.
Multispectral imagery	Imagery that comprises several separate 'bands' of measurements, each covering a defined range of wavelengths. Typically this would be blue, green and red wavelengths, and sometimes includes near-infrared wavelengths.
NMO	See National Mapping Organisation
National Mapping Organisation	A body charged with mapping large regions. This is usually a government body that maps an entire country but can also include federal agencies and private companies with responsibility to national government.
Normalised DSM	A DSM that has been normalised using terrain height information (DTM) for example by subtracting, at all locations, the height of the DTM from the height of the DSM. The resulting model represents the height of features that sit on and above the terrain.
QuickBird	Commercial satellite launched in 2001 collecting panchromatic imagery at 60-70 centimeter resolution and multispectral imagery at 2.4- and 2.8-meter resolutions. http://www.digitalglobe.com
SAR	See Synthetic Aperture Radar
SPOT	To date, 5 SPOT satellite have been launched, the first 3 have been de-orbited or no longer operate. SPOT 5 (launched 2002) offers panchromatic imagery at 2.5 to 5 meter in resolution and multispectral imagery at 10 meter resolution as well as the capability to acquire stereo pairs. Two futher SPOT satellites are scheduled for launch in 2012 and 2013. http://www.cnes.fr/web/CNES-en/1415-spot.php
Satellite imagery	Panchromatic or multispectral imagery obtained from a space-borne orbiting platform.
Stereo aerial imagery	Imagery acquired from an air-borne platform with image overlaps that allow stereo viewing. Recently, it has become more common to acquire image data sets with multiple overlaps so that any point on the ground can be viewed in a number of images.
Synthetic Aperture Radar	A radar remote sensing system that increases the spatial resolution of the resulting data by using the relative motion between the antenna and its target region. Can be mounted on air- or space-platforms
TIN	See Triangulated Irregular Network
Topographic mapping	NMOs use this term to mean large scale mapping of real-world features that are visible on or above the ground. Such maps will feature buildings, roads, waterbodies and areas of vegetation and may also include information about the terrain height and land cover.
Triangulated Irregular Network	A data structure used to represent a surface. A TIN comprises points connected by lines to form a contiguous set of irregularly shaped and sized triangles.
Vegetation / canopy mapping	Mapping that describes the vegetation over an area.
Viewing angle	The angle between the normal to the viewed surface and the viewing direction.

5. The change detection problem

Actuality is a key quality component of current (non-historic) mapping. If mapping is to be kept up-to-date, changes to real-world features that are represented on the mapping must be identified. Many National Mapping Organisations detect changes to real-world features by manual inspection of aerial-, and in some cases satellite-, imagery and by field survey. National Mapping Organisations may also rely on notification by local authorities, data users and organisations contracted to detect change. In a few cases, National Mapping Organisations also receive notification of change by the general public and construction companies (Change detection questionnaire 1, 2010).

It is difficult to estimate the cost of change detection for a mapping agency because it is so fused with their other processes. However, most National Mapping Organisations see automatic change detection as essential to improving their production methods either to save time or cost. As with many government agencies, National Mapping Organisations are experiencing a pressure to reduce staff numbers and costs. A few National Mapping Organisations would also like an automatic change detection method to enable them to detect changes that they are currently unable to. Yet very few National Mapping Organisations have implemented automatic change detection in their production areas; National Mapping Organisations who have started to implement automatic change detection are those of Spain and Greece (Change detection questionnaire 1, 2010).

The reason for such low uptake of automatic change detection solutions is likely to be because the results produced by the solutions are not yet good enough to be of value to the National Mapping Organisation. To be viable as a replacement to manual change detection, automatic change detection needs to identify enough change to meet the quality criteria set by or for the mapping agency. If any manual checking is required, many organisations would consider the automatic method to be redundant.

Of the respondents to a EuroSDR survey (Change detection questionnaire 1, 2010), those that quoted a high success rate using automatic techniques were mainly using solutions written specifically to the requirements of their mapping agency. These more successful solutions had only been used in a Research capacity and so one can surmise that further work is required to make these production-worthy, such as to improve the number of actual changes detected or to detect changes in a wider range of real-world features or simply to make them usable by a range of production staff.

For a change detection solution to be usable by a number of National Mapping Organisations, it would need to apply to the many varied criteria set by and for different agencies. It would need to consistently and accurately detect a high enough proportion of real-world changes for a range of different real-world feature types and do so at a lower cost than the current, largely manual methods being used. What is deemed 'consistent', 'accurate' and 'enough' is different for each mapping agency. However, there are clear common goals and requirements for National Mapping Organisations and we set these out below.

6. Setting priorities

Priorities for change detection are set by various bodies, including government and customer. Within our working group, we found that priorities could be based on the following:

- The priorities of the mapping product (see Mapping products, section 9) for which change detection is required (for example, the topography product is most important)
- The priorities of the mapped features (see Mapped features, section 10) that can change (for example, buildings and roads are more important than coastal features)
- The location that is being mapped can have different priorities (principally for Ordnance Survey, GB where urban areas are more important than rural areas)
- The amount of change that has occurred (e.g. areas of no change or considerable change of most importance)
- The difficulty of detecting change using existing means (i.e. of most importance are those changes that cannot be captured by existing methods)

The features being mapped and the amount of change that has occurred are the most important factors for prioritising change detection (Change Detection Questionnaire 2).

7. Types of change detection

Change detection can take a number of forms and so can mean quite different things to different people. Within the working group, we identified four distinct types of change detection of increasing levels of complexity:

1. Identify regions that have (or have not) changed
2. Alert to individual features that have changed
3. Determination of the type of change that has occurred
4. *(Detect and update changed features)*

Whilst all of these can be achieved manually, using a variety of methods, the goal of any change detection solution would be to automate one or more of these types of change detection.

The first of these is possibly the basic aim of an automatic change detection system. By automatically identifying regions that contain change, a mapping agency can target this region for more detailed manual detection and update.

Many automatic change detection systems to date have attempted to perform the second type of change detection by identifying features that have probably changed. The mapping agency would then rely on a manual process for verifying the change and, if necessary, updating the feature.

The main benefit of automatically determining the type of change that has occurred would be to target those types of change that are a priority for the mapping agency. This type of automatic change detection is probably only of value if performed in conjunction with one or both of the previous two types of change detection.

To keep mapping current, all National Mapping Organisations currently perform the 'detect and update' change detection in a largely manual way facilitated by surveyors and photogrammetric operators as well as notification by various bodies. For some types of mapping (Mapping Products, section 9) such as those that are classed as coverages (e.g. terrain models, land cover maps) automatic update may be achievable, but for many mapping products such as topographic maps, accurate update is still only achievable using manual processes. In fact, it is arguable that 'update' is really part of the change detection problem and National Mapping Organisations do not realistically expect automatic update in the near future. For this reason, we do not regard the fourth type of change detection as an important focus for change detection research.

8. Change detection source data

There are many sources of data from which changes in the real-world can be gleaned. Already mentioned are the different methods of manual survey and sources of notification. When considering automatic change detection, most National Mapping Organisations expect to use remotely sensed data sources since these are one of the most reliable ways to 'sweep' a large area. For this reason, and also because the expertise of the working group is principally in remote sensing, we are limiting the scope of recommended source data to air- and space-borne remote sensing sources.

National Mapping Organisations have a range of remote sensing data available to them. Those data that they use commonly have been selected for their applicability to creating and maintaining the desired mapping products based on criteria such as ability to collect data in a timely manner, ability to map to the desired level of detail from the data and the cost of data. For example, stereo airborne imagery is used for topographic mapping by many National Mapping Organisations.

When specifying on what data an automatic change detection solution should be based, we could restrict ourselves to those data that National Mapping Organisations already access. However, one important point that is worth highlighting is that, because the problem of change detection is so great and costly for a mapping agency, if an alternative data source were to provide enough gains in efficiency or quality then the agency would consider moving to that new data source. In this case, the mapping agency would need to consider the costs of obtaining the new data source in addition to the cost of the change detection solution and determine if they were outweighed by the benefit gained from implementing the solution. For example, few National Mapping Organisations currently use SAR; however if a highly reliable automatic change detection solution required this data source, a mapping agency would consider obtaining these data for future change detection.

The following are the broad categories of data that are used by an automatic change detection solutions:

- Stereo aerial imagery (digital and, to some extent, analogue)
- Digital surface models (DSMs from dense point matching or laserscanning)
- Georectified satellite imagery
- Airborne laserscanning (lidar)
- Synthetic Aperture Radar (SAR)

These categories represent a mix of platforms and sensor types and are the categories by which National Mapping Organisations would consider source data. They are ordered according to the ease by which National Mapping Organisations would, in general, be able to obtain them with stereo aerial imagery being the easiest. More detail is given in the following sections.

8.1. Stereo aerial imagery

Stereo aerial imagery is the most commonly used remotely sensed data for National Mapping Organisations and so a change detection solution based on this would be unlikely to require additional investment in a data source by the mapping agency. Many National Mapping Organisations have moved from analogue to digital cameras. Commonly operated are the Intergraph DMC and Vexcel UltraCam and to some extent the LEICA ADS40/80 line scanners. However, the use of analogue cameras is still wide-spread enough for these data sources to be considered important. Both digital and analogue imagery can be used to create ortho-imagery (images that have been orthorectified) if a terrain model is available. Orthorectification would be particularly useful if change detection uses comparison of recently acquired imagery with mapping data (see section 8.2).

8.2. Digital surface models

DSMs are now available to many National Mapping Organisations either by dense point matching (image matching) technologies applied to stereo imagery or by collecting airborne laserscanning (lidar) data (Change detection questionnaire 1, 2010). They provide information about the upper surface height and shape of features on the ground, such as buildings and vegetation, as well as the ground surface where this is not covered by other objects. DSMs are often considered "2.5D" because, in most cases only one height can exist at any geographic location.

8.3. Georectified satellite imagery

A range of satellite imagery sources have been tested in research into automatic change detection by a number of National Mapping Organisations but none are used in production. Most popular are Ikonos, QuickBird and SPOT (Change detection questionnaire 1, 2010). Some satellite sensors provide a stereo capability but this has not been widely tested for change detection purposes.

8.4. Airborne laserscanning

Most cases when airborne laserscanning or lidar has been used for automatic change detection have been in a research setting only (Change detection questionnaire 1, 2010). However, some National Mapping Organisations collect airborne laserscanning for the creation and maintenance of their digital terrain model data and so could have this available for change detection. Laserscanning can provide more information than a simple DSM because it provides a true point cloud. For example, this can allow vertical walls and terrain under vegetation to be modelled.

8.5. Synthetic Aperture Radar

Few National Mapping Organisations have used SAR, despite the apparent potential (e.g. Dekker, 2005; Grey *et al.*, 2003) quite possibly because of its inherent problems with layover, foreshortening and obstruction (Kellenberger & Streilein, 2010).

8.6. Combinations of source data

Each of the above sources of data provides its own type of information and so better results can be obtained by combining two or more data sources. A popular combination is ortho-imagery and DSM data. Consideration must be made of the time difference between the acquisition of two or more data sources as changes could be present in one source but not the other. This isn't a problem in the case where an ortho-image and DSM have been produced from the same stereo aerial imagery.

9. Change detection method

Put very simply, change detection can take two forms:

- Comparison of two dates of similar source data (e.g. images, DSMs)
- Comparison of recently acquired source data with mapping data to be updated

9.1. Comparison of two dates of similar source data

Change detection is often thought of as the comparison of a recently acquired source data set to an older but similar data set. Consequently, this is often the change detection solution made available within a number of off-the-shelf software packages. However, the differences between two data sources, for example two sets of imagery, can bear little relation to changes that a mapping agency requires for map update. If images are compared 'per-pixel', differences between two dates are as likely to be due to changes in viewing and illumination angle, changes in the season or even sensor calibration and geometric registration as to changes that require map update (Lu *et al.*, 2003).

Therefore, change detection that relies on the comparison of two dates of source data needs to be robust to variations in sensor and environmental factors that are not of interest. One method is to segment or classify the images to produce objects and then compare the objects between the two dates (Gweon, Y & Y Zhang, 2008). Height data such as DTMs and DSMs are less prone to variation due to sensor and environmental factors and so have been used successfully for detecting change (Matikainen *et al*., 2004). Problems with comparing two dates of source data are that the data source can change (e.g. a new camera system is purchased) and that archived data are difficult to obtain.

9.2. Comparison of recently acquired source data with mapping data

Here, more effort needs to be applied to transforming the source data into a map-like data set or vice versa. In the case of mapping that is in the form of a coverage (see section 9) such as a terrain model (DTM) or tree density map, simply creating a new version of the mapping and then directly comparing this to the older mapping could be undertaken. Another approach could be to use changes in related object-based mapping to flag regions where the coverage may need updating.

Automatic change detection by comparing a current source data set to object-based mapping (see section 9) is possibly the most challenging of all change detection problems but it is potentially the most beneficial to National Mapping Organisations. This is because it addresses the most difficult change detection task for NMOs and eliminates the problems associated with archived data. In this case, the source data may be transformed to be similar to the mapping data. For example, Belgium and Ordnance Survey (GB) have developed solutions that use digital aerial imagery (and in the case of OS, normalised DSM data) to create an object-based 'classification' for comparison to object-based mapping. Alternatively, it may be possible for the map data to be transformed to have similar characteristics as the source data.

10. Mapping products

Ultimately, automatic change detection is aimed at updating one or more map products. Across Europe, quite a range mapping products are available and, since what changes are relevant depend on what is represented by the mapping product, it is pertinent to simplify the range. Within our working group, we found products fall into the three categories: object-based mapping, coverages and networks. For the present time, automatic change detection is still far from being realised, we would recommend limiting the scope of any work into automatic change detection to object-based mapping and coverages. In many cases, the network mapping produced by National Mapping Organisations would be updated when updating other mapping such as topographic maps.

10.1. Object-based mapping

The main types of object-based mapping focused on by National Mapping Organisations are:

- topographic
- land-cover
- cadastral
- land-use

In topographic mapping, real-world features such as buildings, roads, waterbodies, vegetation and other man-made and natural features are depicted by points, lines or polygons in vector data or regions of defined values in raster data. In land cover mapping, the physical cover of the Earth is represented as a set of classes. At the very least, these classes would be 'vegetation', 'water', 'man-made material' and 'unvegetated natural surface'.

Most cadastral and land-use information is obtained by means other than remote sensing and so we would not expect change detection using remote sensing to specifically target this type of mapping. Similarly, mapping that is based on non-physical features, such as administrative boundaries or address data, is beyond the scope of automatic change-detection by remote sensing methods.

10.2. Coverages

Other common map types are:

- terrain height (e.g. DTM)
- natural variables (e.g. DSM, tree density or canopy height)

Terrain maps are provided by most National Mapping Organisations. These show the height of the 'bare Earth' (with man-made structures and vegetation removed) across the entire mapped region. These are more often now in the form of a digital terrain model which contains terrain heights as 'posts' or points on a grid or irregularly spaced (sometimes with breaklines) or as a TIN (sometimes with breaklines). Terrain height can also be represented as contours.

Other coverages in use by European National Mapping Organisations are those that depict other natural variables such as tree density, canopy height, or more generally a digital surface model in which a grid or TIN of height indicate the upper most height of objects on the ground.

10.3. Mapping Scales

Mapping scales vary greatly across the European region and, with a move to digital mapping, it is difficult to specify which mapping scales should be accommodated within automatic change-detection. However, it is relevant to talk about scale in terms of the minimum size (area, length, height, etc) that a feature should be to be mapped. Additionally, scale is relevant when considering the minimum size that a feature should have changed for the mapping to be updated. Therefore, scale is more relevant to the feature being mapped (section 10) than the mapping product.

Currently, it seems that these feature- and change-size thresholds are too diverse within our group of National Mapping Agencies to be generalised. If generalisation is possible, this should be drawn out in the practical exercise proposed in Appendix B: Next steps.

11. Mapped features

There are a great many real-world features that are depicted on mapping and it is likely that many features have a subtly different definition in each mapping agency. In particular, different National Mapping Organisations have different definitions of the size that a feature should be to be mapped or, indeed, the amount that a feature should have changed for the mapping to be updated (see Mapping Scales, section 9).

Our working group identified a considerable list of features using various media including two questionnaires (Change detection questionnaire 1, 2010; Change detection questionnaire 2, 2011). Of these features, 5 general interest mapped features categories have been identified:

- Building features
- Road features
- Terrain features
- Waterbody features
- Vegetation features

More detail on these features is provided in Appendix A. These categories include those mapped features that are of importance to the widest range of National Mapping Organisations. Features that are not included in these topic areas (such as railways) are of no or low importance to most National Mapping Organisations or are of known high importance to only one mapping agency. Other features, such as airports, are aggregations of many included features, such as buildings and roads, and so changes in these areas would be picked up by detection of changes in buildings and roads.

One further optional general interest mapped feature can also be included in this list:

- Unvegetated natural surface

This feature is only of importance to National Mapping Organisations producing a land-cover mapping product.

11.1. Change process and changed component

It seems pertinent to further define what change to these real-world features actually entails to better define what is required of a change detection solution. Change can take many forms and those that we could reasonably expect to be identified using remote sensing could be the following:

- Existence Change
  - Creation
  - Removal
- Geometric Change
  - Amalgamation
  - Subdivision
  - Extension
  - Shrinkage
  - General shape change
- Attribution Change
  - Continuous value change
  - Thematic change

Further, the aspect of the feature that is changed can vary. The components of mapped features that change are:

- 2D outline
- 3D shape/Form
- 2D centreline

- 3D centreline
- Attribute

In Appendix A: Mapped features, each general interest mapped feature category is described. For each, the salient features and characteristics are identified and how change manifests in terms of the type of change and the feature component to which the change occurs.

This list of general interest mapped features has been simplified into a group of recommended topic areas which area detailed in Automatic change detection topic areas (section 11).

12. Automatic change detection topic areas

Automatic change detection that focuses on detecting change in only one type of mapped feature, although useful, may not produce an efficient solution to the change detection problem because the regions would probably have to be manually screened to identify change in other features. Therefore, we recommend that change detection solutions focus on detecting change in one of four defined topic areas. These are:

- Terrain and surface model
- Buildings and roads
- Vegetation areas
- Waterbody

13. Change detection solutions

From the discussions in our first meeting, it was clear that our definitions for mappable features can be quite different. For example, one country may only map rivers that are greater than a 3m whereas other may attempt to map all watercourses. Similarly, we could each have very different thresholds for notable change (change that would require us to update our mapping). For example, a terrain height difference of 0.5m may require an update to a data model for one country but not another. Further, we would probably all have different requirements for how much confidence we had in the detected change. Therefore, we proposed that, to be applicable to a range of National Mapping Organisations, change detection solutions would need to allow the National Mapping Organisation to set parameters in at least these three types of information (feature description, change amount and change confidence) and possibly more.

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Appendix A: Mapped features

Building features

Definition:

Roofed constructions with foundations, showing some permanency and that can be occupied. Has defined boundary usually of a regular geometry and is mapped using object-based mapping.

Salient features:

- Buildings
- Building height (at least: maximum height of main building)
- Roof aspect (at least: North, East, South, West)

Building features changed components:

- Existence Change to building
- Geometric Change to 2D outline of building
- Attribute Change to building height
- Attribute Change to roof aspect

Road features

Definition:

Mainly linear man-made feature concerned with the movement of people and vehicles (not railway, canal, runway). Has defined boundary usually of a regular geometry. Applies to object-based mapping.

Salient features:

- Roads
- Under-/Overpass/Bridge
- Road material (at least: made or unmade)

Optionally includes:

- Roundabout
- Pavement'
- Car park'

Road features changed components:

- Existence Change to road
- Geometric Change to 2D outline of road
- Geometric Change to 2D centreline of road
- Geometric Change to 3D shape of Under-/Overpass/Bridge
- Attribute Change to road material (made or unmade)

Terrain features

Definition:

The elevation of the ground surface of the land without vegetation or buildings. Represented by continuous height values in a coverage or by some objects (e.g. cutting, embankment).

Salient features:

- Terrain height
- Cutting
- Embankment
- Landslip

Terrain features changed components:

- Geometric Change to the 3D form
- Existence Change to embankments, cuttings and landslips

Waterbody features

Definition:

Natural or man-made feature that contains water (either continuously or ephemerally). Includes flowing features such as rivers, canals and streams and standing water bodies such as lakes, ponds and reservoirs. Applies to object-based mapping.

Salient features:

- Waterbody
- Watercourse

Optionally includes:

- Standing water body

Waterbody features changed components:

- Existence Change to waterbody
- Geometric Change to 2D outline of waterbody
- Geometric Change to 2D centreline of watercourse

Vegetation features

Definition:

Areas that are largely covered by terrestrial vegetation such as trees, shrubs, grasses and other flowering plants. Can be represented by defined regions in object-based mapping or as a coverage. The latter can be continuous values (such as tree cover) or thematic values (such as land cover). We are interested in the following types of area: Tree- and shrub-covered areas, Areas of low cultivated vegetation (agricultural land), Areas of low managed vegetation (recreation and amenity land), Wetland areas and Areas of natural vegetation (including moors).

Salient features:

- General vegetation area
- Tree- and shrub-covered area
- Area of low cultivated vegetation
- Area of low managed vegetation
- Wetland area
- Areas of natural vegetation
- Tree height
- Tree density
- Vegetation cover
- Tree cover
- Vegetation type

Vegetation features changed components:

- Existence Change to Vegetation area
- Geometric Change to 2D outline of Vegetation area
- Thematic change to vegetation type
- Thematic change to land cover type
- Continuous value change to tree height attribution in object-based mapping or coverage
- Continuous value change to tree density attribution in object-based mapping or coverage
- Continuous value change to vegetation cover in coverage
- Continuous value change to tree cover in coverage

Unvegetated natural surface

Definition:

A natural surface that is not a vegetation/vegetation area or water/waterbody but which is covered by bare soil, sand and shingle, rock or permanent snow and ice. Of interest in land cover mapping.

Unvegetated natural surface changed components:

- Thematic change to land cover type

Appendix B: Next steps

Following the definition of the topics on which automatic change detection research should focus, our working group consider that it would be valuable to undertake a series of tests on real data to identify how well any available automatic change detection solutions perform in each topic area. An additional benefit of running such a test would be to encourage deeper thinking within NMOs about how they define change and how they would like automatic change detection to operate for them.

We have already found that different National Mapping Organisations have different configurations in terms of priorities (section 5), available source data (section 7), products (section 9) and features (section 10). Therefore we suggest that the National Mapping Organisations involved in our working group could each compile test data sets for each topic area that is of importance to them.

These test data sets would contain for the same geographic region:

- remotely sensed source data (such as imagery, DSMs, etc)
- relevant mapping products or data with an update date of earlier than the remotely sensed data
- verification data
- data set guide
- where available, remotely sensed data (imagery, DSMs, etc) from a date of earlier than the source data

The verification data should be a geographic layer of known changes (derived from the NMO's standard change detection process) or a set of mapping data from after an update that is based on data and/or fieldwork from a similar date to the remotely sensed data.

The data set manual should contain the specification of all the data sets provided, including (as appropriate):

- sensor type and model or capture method
- data resolution (spatial, radiometric)
- data acquisition/capture date and time
- criteria used by NMO for defining features or change (e.g. minimum area of changed object)

We propose a next step for this working group is to compile these data sets so that researchers and vendors of automatic change detection solutions could then test their solution on the data sets for the appropriate topic area(s).