Capturing loss and change in Danish protected nature areas using object based image analysis tools

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› The Paragraph 3 nature habitat network in Denmark
› The problem
› Object based image analysis
› Three examples of OBIA §3 loss / change mapping
  › loss of small water bodies
  › general change in a “heathland” area
  › bush encroachment
› Summary & Discussion Points
Nature habitat protection in Denmark:

- EU Habitat Directive
  - Natura2000 network of sites of Annex-1 habitats
  - assessment of conservation status
  - management & monitoring activities

- “paragraph-3” (§3) nature areas
  - from 1991 nature & environment protection law
  - designated areas
  - protected from loss or change by law
Natura2000 network in DK
- 261 habitat areas
  - land: 3,590 km² (8.3% of DK)
  - sea: 18,686 km²

Paragraph 3 nature
- 238,797 protected areas
  - 4,072 km² (9.5% of DK)
- 6 nature types: water bodies, meadow, marsh, saltmarsh, heath, dry grassland
Paragraph 3 nature

- initial mapping registration 1991 – 1996
- responsibility of local authorities
- piecemeal update to registration
  - case-by-case as issues arose
  - as part of planning permission processes

- **LAW: §3 areas are protected against loss or change!**
  - many in Danish nature could see signs of failings in this law

- ca. 2006 → Danish Environmental Portal (www)
The Danish Environmental Portal, Areal Information

http://www.miljoeportal.dk/Arealinformation/ (most in Danish)

everyone can access the spatial data ... web map

including §3 areas & biennial orthophotos (national coverages)
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- everyone can access the spatial data … web map
  - including §3 areas & biennial orthophotos (national coverages)
… enter Peter Størup … ca. autumn 2008

a private individual and a nature enthusiast
decided to check-out a sample of §3 areas via the Portal images

showed the true extent of §3 area loss and change

mass-media coverage

various follow-up studies to scientifically assess the situation
calls for tools to help authorities with §3 map update & monitoring

object-based image analysis

How can image data be transformed into useful map information?

3 options

visual interpretation
manual mapping

automated digital image analysis

pixel based mapping

object based mapping

each image pixel is analysed independent of the neighbouring pixels

image pixels combined to relate to real world objects

e.g.: level-slicing, supervised classification

"classical" image-based mapping

requires post-processing to map objects, e.g. areas

image segmentation

→ object labelling

major advances in the last 5-10 years

→ more direct way to map the required objects

→ e.g. vector GIS file
why consider Object-based image analysis (OBIA)?

- OBIA integrates remote sensing and GIS mapping approaches
- OBIA enables many mapping solutions that simply cannot be done through pixel-based image analysis methods
  - “... important semantic information necessary to interpret an image is not represented by single pixels” – Brodsky et al., 2008
- OBIA is particularly useful where the image pixels are far smaller than the items to be mapped, such as for discrete “target” mapping e.g. buildings, roads, ships, birds, etc.
- OBIA has parallels to manual image mapping:
  - cognitive abilities, image primitives
- OBIA is highly modular, controllable & versatile
  - use your imagination ... its probably possible!
- OBIA interfaces well to other object orientated methods, e.g. databases & modular hierarchical models, and GI-science issues e.g. map ontology, semantics
overview of object based image analysis

RS as an information extraction problem
i.e. transform image data into useful information

understand the required information in terms of image patterns
translate patterns into OBIA possibilities

image data
pixel IA, e.g. FCC, stretch

image data

segmentation

label objects
object relationship modelling
filtering rule-based / fuzzy

required mapping

ESRI shape e.g. markblok polygons

mapped information

an OBIA algorithm

full OBIA process

programmable
repeatable
adaptive
can be simple or very complex, e.g.
nested hierarchy of segmentations
use external map data
how can OBIA be done?

- requires:
  - advanced multiscale image data segmentation
  - databasing for object relationship modelling
  - object labelling rules and functions
  - frontend for algorithm development & operation

- Trimble eCognition software (formerly “Definiens Earth”)
  - mid-late 1990s: major advances in fundamental OBIA ideas
  - ca. 2000: first software implementation
  - ca. 2005: first version for programmable algorithm development and operation, and batch processing with GRID computing

- from 2007 used in NERI
  - vegetation mapping: stressed birch forest, N.Norway
  - mapping of bird individuals (sea ducks, flamingos, kestrels, …)
  - automation to EU CAP control mapping needs in Denmark
  - automated Paragraph-3 loss & change map update
• introduction to object based image analysis

  > the eCognition workspace

  image, with top-level segmentation (markblok)

  image, with sub-level segmentation (quadtree)
• introduction to object based image analysis
  › the eCognition workspace

one image object
feature data on this object
• introduction to object based image analysis

  ▶ the eCognition workspace

  OBIA algorithm for this mapping task

  - do (To map the exact extent of anomalies within a MB)
    - do (Complete and OK (for Bnr=495245-81 : 10h06)
    - do (Getting the Process Mask from a SHP)
    - do (QG60 segmentation below Top & map the homogenous cropping extent)
      - do (onMBmask at TopLevel: copy creating 'subMBq60seg' below)
      - do (0.016 onMBmask at subMBq60seg: quadtree: 60)
      - do (0.016 onMBmask with Area => 1024 Pxl at subMBq60seg: _temp1)
      - do (0.016 at subMBq60seg: _temp1 with _OY_sdist:2.MN._temp1.layer1 > ( abs ([Mean Layer 1]-[Layer mean of Layer 1])), _temp1 with _OY_sdist:2.MN._temp1.layer1 > 2 at subMBq60seg: onMBmask)
      - do (0.016 onMBmask with Area => 256 Pxl and Rel. border to _temp1 > 0 at subMBq60seg: _temp2)
      - do (0.016 _temp2 with Mean diff. to Layer 1, _temp1 <= 15 at subMBq60seg: _temp1)
      - do (0.016 _temp2 at subMBq60seg: onMBmask)
  - do (get the objects close to the field edge & merge)
  - do (Complete and OK (for Bnr=495245-81 : 10h06)
  - do (Merging and clean-up)
    - do (Separating the different types of fraud out of the anomalies)
      - do (segmentation)
        - do (_temp3 at subMBq60seg: 10 [shape:0.1 compct.:0.5]
        - do (_temp3 at subMBq60seg: spectral difference 15)
    - do (Export objects to shape polygons)
      - do (onMBmask at subMBq60seg: export object shapes to ObjectShapes)
Three examples of OBIA §3 loss / change mapping solutions
- loss of small water bodies
- general change in a ”heathland” area
- bush encroachment

Three different §3 loss / change situations
Three different OBIA solution strategies
Each addresses the same set of core issues:
- automation of use of image data
- provide information to reduce manual mapping / fieldwork
- work with clear design criteria
Case 1: Loss of small water bodies

The §3 legislation protects water bodies down to 100 m²

- of the 120,000 protected water bodies 98% are < 1 ha
- many are associated with agricultural land, i.e. within fields

but many have gone!

- particularly in areas such as Lolland:
Case 1: Loss of small water bodies: orthophotos

1995 §3 registration
Case 1: Loss of small water bodies: orthophotos

1995

§3 registration

1999
Case 1: Loss of small water bodies: orthophotos

1995

1999

2008

§3 registration
Case 1: Loss of small water bodies: orthophotos

What evidence in the images enables our visual interpretation “this §3 area has been lost”?

A key piece of evidence:
- Presence / absence of a difference in image data local variability between the registered area and the adjacent land

Can that evidence be exploited through OBIA methods?
Case 1: Loss of small water bodies: OBIA method

1. §3 registration ➔ objects
2. irregular polygon image data based segmentation OUTSIDE the §3 areas
3. image data based merging of field objects

C.Var. comparison between §3 object and adj. object with largest common border to §3 area

§3 area loss information, based on threshold of C.Var. difference
(traffic light colour scheme)
Case 2: general change in a “heathland” area: Fur
Case 2: general change in a “heathland” area: Fur 1995
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Case 2: general change in a “heathland” area: Fur

1995

1999

2008
Case 2: general change in a “heathland” area: Fur

- Change 1999 - 2008
  1. §3 registration → objects
  2. Irregular polygon T1 image data based segmentation within the §3 areas + image data based merging of field objects
  3. Coarse chessboard segmentation over §3 area image sub-objects (respectful of slivers)

= Spatial base for the change analysis
Case 2: general change in a "heathland" area: Fur

4. fine grain irregular polygon T2 image data segmentation

5. 2 degrees of HSI* colour space T1 – T2 difference scoring for the T2 objects + summation over the scores
   * optional (several possibilities ... PCA, MAD-MAF, NDVI, TCap)

6. % area of apparent change assessment for each of the T1 analysis base objects, weighted for degree of apparent change (traffic light colour scheme)
Case 3: bush encroachment over grass heath: Mols
Case 3: bush encroachment over grass heath: Mols

T1 orthophoto, 1999

T2 orthophoto, 2008

Strategy:

- map the bushes apparent in the T2 image data
- interrogate the T1 image data for “bush” signatures at the same locations
Case 3: bush encroachment over grass heath: Mols

1. Quadtree segmentation of the T2 image data
2. Labelling of dark T2 image data → shadow seeds
3. Merging + growing of the shadows seed objects
4. Interrogation of T1 image data for the T2 shadow objects: 
   \[(a-b)/(a+b)\] between  
   T1 layer-2 5% & T2 layer-2 95%
5. Assessment of bush increase
Summary & Discussion Points

3 different issues and situations

3 different OBIA mapping strategies:
- case 1: loss of small in-field water bodies
  - “inside-outside” comparison
- case 2: general change
  - simple image differences scoring tool
- case 3: a specific local habitat change:
  - location specific Time1-Time2 image comparison

There will not be a “one size fits all” solution for “habitat” mapping and monitoring
- the real world is too complex for that
- use the tools available to “reduce complexity” to increase choice and possibilities (Luhmann)
Summary & Discussion Points

- Develop OBIA algorithms that are:
  - robust (operate invariantly) against target (i.e. real world) and image scene vargaries
    - e.g. exploit object properties less variable than image tone
  - adaptive for within-scene and between-scene differences
    - e.g. that dynamically interrogate the image data and rule-related situations for the setting of rule thresholds
Summary & Discussion Points

Working with aerial orthophoto image data:

Remember:

- these are relatively simple image data
- they are often spatially rich but radiometrically poor
  - the data values (pixel-DN) are often not fully representative of at-sensor radiances (due to resampling, colour re-composition and compression) … let-alone surface reflectances
- it may not be so easy to use these image data in statistical, parametric ways
- which is why OBIA possibilities are relevant
supervised image mapping in OBIA?
yes, it is possible, but:
the object features it uses still need to be selected
(and to just use image tone features represents an under-utilisation of OBIA)
that selection still has an element of working “in the dark”
... but now the “dark” is a lot deeper!

OBIA is a new paradigm for RS mapping
- so dare to think differently
- consider moving away from standard RS PBIA practices

for use of OBIA to mimic manual image mapping “working beyond PBIA” is imperative!
Summary & Discussion Points

- OBIA segmentation:
  - consider use of Quadtree segmentation, rather than just irregular polygon (so-called “multi-resolution segmentation”)

- a Quadtree segmentation strength:
  - a fixed, known, set of object sizes (power-4 size sequence)
  - useful for use of object size filter rules
Thank you.