Supervised classification of water regions from lidar data in the Wadden Sea using a fuzzy logic concept

Alexander Brzank
content

- introduction
  - the Wadden Sea
  - determination of a DTM - workflow
- classification
  - features
  - workflow
- parameters
  - automatic determination
- examples
- summary
the Wadden Sea

- area of 450km x 20km
- located at the coast of the Netherlands, Germany and Denmark
- flooded two times a day
- tidal range: 2 – 4m
<table>
<thead>
<tr>
<th>Introduction</th>
<th>Classification</th>
<th>Parameters</th>
<th>Examples</th>
<th>Summary</th>
</tr>
</thead>
</table>

the Wadden Sea
applications of Digital Terrain Models in coastal areas

• monitoring of coastal protection facilities (i.e. dikes)
• morphological change detection (dunes, tidal creeks)
• planning information for the management of coastal protection facilities
• modelling flood risk scenarios
• hydrographic numeric modelling
• supplement to bathymetric surveys

goal: precise DTM
Institut für Photogrammetrie und GeoInformation

airborne laser scanning

- high point density
- accuracy: $\sigma_h < 15\text{cm}$, $\sigma_x < \sigma_y < 50\text{cm}$
- moderate costs
- capability to cover large areas in short time

**determination of a precise DTM possible, but...**
DTM-Generation in the Wadden Sea - difficulties

**tidal area**

- area partly covered with water
- laser beam reflected at water surface

DEM includes partly water points

\[ \text{task} \]

- classification (filtering) of water points within Lidar data
DTM-Generation in the Wadden Sea - difficulties

- processing of raw data of every flight strip
- deletion of gross and systematic errors
- flight strip adjustment
- classification of Lidar data into water and mudflat
- fusion of bathymetric and Lidar data
- extraction of structure lines
- modeling of terrain surface

work flow
systematic dependency of intensity and 2D point density

- systematic dependency of intensity $I$ and 2D point density $P$ in relation to the angle of incidence $\beta$
- negative correlation between $\beta$ and $I$ as well as $\beta$ and $P$
- directed reflection
classification of Lidar data in water and land points

- supervised classification
- classification based on raw data
- analysis of several features (height, intensity, 2D point density)
- using Fuzzy-logic
- individual weight depending on applicability of every feature
- consideration of changes of feature values depending on the angle of incidence
classification of Lidar data in water and land points

- raw data
- training area
- Flight path

**classification**
- automated determination of parameters (thresholds, weights)
- calculation of membership value class water for each raw point
- classification of points with a water threshold
- features: height, intensity, point density 2D

**plausibility**
- analysis of profiles (along and across flight direction), removal of isolated objects, low-pass filtering

- classified and controlled points

- classified points
- parameter plausibility
classification of Lidar data in water and land points

classification method

• transformation of crisp feature values into fuzzy membership values

\[ \mu(h, i, p, \alpha) = \frac{\delta_H \mu_H(h) + \delta_I(i, \alpha) \mu_I(i, \alpha) + \delta_P(p, \alpha) \mu_P(p, \alpha)}{\delta_H + \delta_I(i, \alpha) + \delta_P(p, \alpha)} \]

• calculation of the entire membership value

• classification of each scan line with a threshold
classification of Lidar data in water and land points

plausibility

- control height at classification changes for each scan line
- delete isolated segments
- control height at classification changes along track
- low pass filter in order to smooth the classification result
determination of classification parameters

- calculation of mean height and standard deviation
- fitting adjusted functions through intensity and point density values depending on the angle of incidence
- calculation of individual weights
- calculation of a membership value for each feature and point
- calculation of mean entire membership value and standard deviation
- determination of the classification threshold

![Graph showing probability density and membership value with a threshold](image)
Friedrichskoog May 2005
Juist april 2004
summary

• supervised classification to separate water and land points based on raw lidar data

• features: height, intensity and 2D point density

• calculation of individual weights depending on overall discrimination for each feature and the angle of incidence (intensity and 2D point density)

• additional plausibility checks in order to get a consistent classification result
Thank you for your attention!
summary

In the graph, two distributions are plotted: one for water and one for mudflat. The x-axis represents height, and the y-axis represents the frequency or density of occurrence. The water distribution is characterized by a higher peak and a narrower spread compared to the mudflat distribution, indicating different characteristics or properties between the two types.