POLITECNICO DI TORINO
Repository ISTITUZIONALE

Onboard Deep Lossless and Near-Lossless Predictive Coding of Hyperspectral Images With Line-Based Attention

Original
Onboard Deep Lossless and Near-Lossless Predictive Coding of Hyperspectral Images With Line-Based Attention / Valsesia, D., Bianchi, T., Magli, E.. - In: IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. - ISSN 0196-2892. - 62:(2024). [10.1109/tgrs.2024.3465043]

Availability:
This version is available at: 11583/2995343 since: 2024-12-19T13:47:58Z

Publisher:
IEEE

Published
DOI:10.1109/tgrs.2024.3465043

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright
IEEE postprint/Author's Accepted Manuscript

©2024 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collecting works, for resale or lists, or reuse of any copyrighted component of this work in other works.

(Article begins on next page)

13 November 2026

Philica
Where ideas are free

Image segmentation applied to satellite imagery for monitoring water in lakes and reservoirs

Amelia Carolina Sparavigna (Department of Applied Science and Technology, Politecnico di Torino)

Published in enviro.philica.com

DOI: 10.5281/zenodo.1288529

Abstract
Here we show that a method of image processing, an image segmentation recently developed and used for the analyses of micrographs, can be applied to the monitoring of the water in lakes and reservoirs by means of the related satellite imagery. The image segmentation allows measuring surfaces and perimeters of the inundated basins. Here the segmentation is applied to the Sarygamysh Lake in Central Asia.

The monitoring of rivers, lakes and reservoirs is fundamental for meeting the human need of water and for assessing ongoing climatic changes [1]. This monitoring can locate quickly the problem of regional droughts as well as help in the estimation of the crop production for the regions that are downstream from the monitored lakes and water reservoirs. Of these basins, the inundated surfaces and the time variations of their extent can be easily evidenced by the satellite imagery, as we can see, for instance, by means of Google Earth and its time-series of images. In addition, the data of the heights of several large lakes around the world are available publicly from the web site of the United States Department of Agriculture [2], which is providing the related radar altimeter data. In [3], for instance, we used these altimetric data for studying the behavior of some lakes in Africa (Nasser, Tana, Chad and Kainji) by means of recurrence plots.

As stressed in [4], the presence of large reservoirs along rivers can be used to generate hydropower and to store water for irrigation and for the needs of urban areas. For this reason, the reservoir managements are critical, particularly for trans-boundary basins, where coordination between riparian countries is necessary [4]. This is especially true when the water resources are shared between countries having potentially opposite interests. Moreover, in the case of semiarid regions, it can happen that the downstream users of water "may be totally reliant on upstream reservoir releases". The research in [4] is considering the example of the Syrdarya river in Central Asia, giving remote sensing data from radar altimetry and optical imagery, to highlight the importance of satellite data for the monitoring of water resources.

Other researches on the subject are given in [5-20]. Among these references, we find works on specific regions and on global scale. For instance, in [5], the researchers have investigated the Pantanal wetland in South America, using radar satellite imagery. In [6], the remote sensing for long-term monitoring is considered for the study of climatic change; the research is concerning a technique, which derives the lake level changes from TOPEX/POSEIDON geophysical data. In [8], measurements use the chlorophyll-a (chl-a) concentration in lake water, which can be monitored with airborne (or space-borne) optical remote sensing instruments. In [20], it is shown that bands 6 and 7 of the MERIS spectrometer allow the detection of cyanobacteria, if they

are present in relatively high quantities. Actually, cyanobacterial blooms can present treatment problems of water and hazards to human and animal health.

The use of images from space for monitoring lakes was discussed also in [21-24], for the case of the Toshka Lakes and the Merowe reservoir. In both cases, it is the water of the Nile being involved. In the case of the Toshka lakes, the water of the Nile is conveyed from the Nasser Lake through a canal in the Toshka Depression. From space, the astronauts of the International Space Station noticed the growing of a first lake, the easternmost one, in 1998. Then additional lakes grew in succession due west, the westernmost one between 2000 and 2001. The satellite images showed that, from 2006, the lakes started shrinking. Today, we can easily see the evolution of the Toshka lakes in the time series of Google Earth. Let us note that, as stresses in [25], water management models are fundamental for the future of the Toshka depression. The same is true for other lakes, like Lake Urmia for instance [26,27].

Besides the Toshka and Urmia Lakes, another striking example (the most popular one) of the human influence on the environment is the Aral Sea, formerly one of the four largest lakes in the world [28]. The Aral Sea has been shrinking since at least 1850, although with some interruptions. "Early in the 20th century, the shrinking was blamed on the rate of evaporation exceeding the rate of inflow; … Shrinking has accelerated since the 1960s after the rivers that fed it were diverted by Soviet irrigation projects. … Satellite images taken by NASA in August 2014 revealed that for the first time in modern history the eastern basin of the Aral Sea had completely dried up. The eastern basin is now called the Aralkum Desert" [28,29].

Approximately midway between the Caspian Sea and the Aral Sea, it is situated the Sarygamysh Lake [30]. Today, the main source of water of Sarygamysh Lake is a canal from the Amu Darya. Some water from the surrounding irrigated lands is also feeding the lake [30]. This lake "and many other "unintended" lakes, such as Aydar Lake on the Syr Darya" [30] are receiving the water that in the past was flowing in the Aral Sea. Here we use the Sarygamysh Lake for applying an image segmentation, recently developed and used for the analyses of micrographs [31-39], to the satellite imagery for monitoring water in lakes and reservoirs. The segmentation is based on a thresholding, which is converting the input image into a black and white one. Then, the black and white image is “segmented” in order to find the black domains and measure their area and perimeter.

First, let us consider three satellite images from Google Earth, here shown in the Figure 1.



Figure 1: The Sarygamysh Lake in three images from Google Earth.

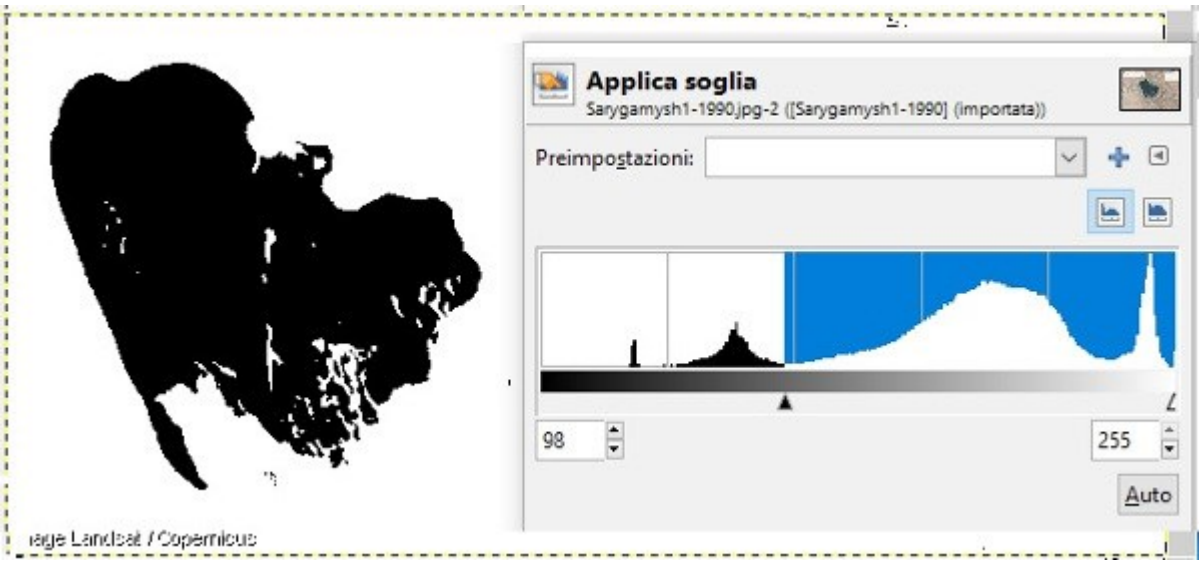


Figure 2: Thresholding of an image, to render it in a binary (black and white) image, obtained by means of GIMP, the GNU Image Manipulation Program.



Figure 3: The binary images obtained from the images in Figure 1.

Each of the images is thresholded by means of a visual inspection of the histograms of the corresponding gray-tones. An example of thresholding in given the Figure 2 for one of the images in Figure 1. The best choice of the threshold is given by a gray-tone value between two peaks of the histogram.

After the thresholding, we have the binary images in the Figure 3. Applying the segmentation proposed and discussed in [31-39], we obtain areas and perimeters of the "segments", which are the black domains. The three largest segments in the image are representing the inundated surfaces of the lakes for years 1990, 2000 and 2015.

The processed image, like that shown in the Figure 3, was 801 x 280 u^2, where u was the size of its square pixel. The first domain on the left has an area of 30769 u^2 and perimeter 1713 u long. In the middle, the domain has an area of 35299 u^2 and perimeter of 1053 u. On the right, we have the domain having the largest area, 37225 u^2, and the smallest perimeter, 926 u. It means that from 1990 to 2015, the inundated surface had increased of about 21%. It is also easy to have a correspondence between the size of the pixel and the meters

on earth's surface. In the case of Google Earth, the software is providing a ruler for measurements, and also elevation profiles (an example is given in the Figure 4). In the case of the Figure 3, u corresponded to 333 meters. Therefore, the surface of the lake passed from 3412 km^2 to 4128 km^2 in 25 years.



Figure 4: An elevation profile of Sarygamysh Lake that we can obtain by means of Google Earth.

Actually, the date of an elevation profile, as that shown in Fig.4, is not given. Moreover, it seems not possible to have a time-series of elevation profiles. For this reason, an estimate of the variation of the volume of water in the basin is not immediate.

Here we have shown that an image segmentation, which has been developed and used for the analyses of micrographs [31-39], can be applied to the monitoring of lakes and reservoirs. After a thresholding of the satellite images, surfaces and perimeters of the inundated basins can be measured. The proposed approach has been applied to the Sarygamysh Lake in Central Asia.

References

[1] Calmant, S., Seyler, F., & Cretaux, J. F. (2009). Monitoring Continental Surface Waters by Satellite Altimetry, Surveys in Geophysics, 29(4–5), 247–269. DOI: 10.1007/s10712-008-9051-1

[2] USDA, at www.pecad.fas.usda.gov/ cropexplorer/global_reservoir/

[3] Sparavigna, A. C. (2014). Recurrence Plots from Altimetry Data of Some Lakes in Africa, International Journal of Sciences, 3(7), 19-27. DOI: 10.18483/ijSci.534 , arXiv:1410.0850 [physics.data-an]

[4] Crétaux, J. F., Biancamaria, S., Arsen, A., Bergé-Nguyen, M., & Becker, M. (2015). Global surveys of reservoirs and lakes from satellites and regional application to the Syrdarya river basin. Environmental Research Letters, 10(1), 015002. DOI: 10.1088/1748-9326/10/1/015002

[5] Costa, M. P., & Telmer, K. H. (2007). Mapping and monitoring lakes in the Brazilian Pantanal wetland using synthetic aperture radar imagery. Aquatic Conservation: Marine and Freshwater Ecosystems, 17(3), 277-288. DOI: 10.1002/aqc.849

[6] Birkett, C. M. (1995). The contribution of TOPEX/POSEIDON to the global monitoring of climatically sensitive lakes. Journal of Geophysical Research: Oceans, 100(C12), 25179-25204. DOI: 10.1029/95jc02125

[7] Lindell, T., Pierson, D., & Premazzi, G. (1999). Manual for monitoring European lakes using remote sensing techniques. Joint Research Centre, Ispra, Italy.

[8] Koponen, S., Pulliainen, J., Servomaa, H., Zhang, Y., Hallikainen, M., Kallio, K., Vepsäläinen, J., Pyhälahtia,T. & Hannonen, T. (2001). Analysis on the feasibility of multi-source remote sensing observations for chl-a monitoring in Finnish lakes. Science of the total environment, 268(1), 95-106. DOI: 10.1016/s0048-9697(00)00689-6

[9] Dekker, A. G., Vos, R. J., & Peters, S. W. M. (2001). Comparison of remote sensing data, model results and in situ data for total suspended matter (TSM) in the southern Frisian lakes. Science of the Total Environment, 268(1), 197-214. DOI: 10.1016/s0048-9697(00)00679-3

[10] Gómez, J. A. D., Alonso, C. A., & García, A. A. (2011). Remote sensing as a tool for monitoring water quality parameters for Mediterranean Lakes of European Union water framework directive (WFD) and as a system of surveillance of cyanobacterial harmful algae blooms (SCyanoHABs). Environmental monitoring and assessment, 181(1-4), 317-334. DOI: 10.1007/s10661-010-1831-7

[11] Sawaya, K. E., Olmanson, L. G., Heinert, N. J., Brezonik, P. L., & Bauer, M. E. (2003). Extending satellite remote sensing to local scales: land and water resource monitoring using high-resolution imagery. Remote sensing of Environment, 88(1), 144-156. DOI: 10.1016/j.rse.2003.04.006

[12] Chopra, R., Verma, V. K., & Sharma, P. K. (2001). Mapping, monitoring and conservation of Harike wetland ecosystem, Punjab, India, through remote sensing. International Journal of Remote Sensing, 22(1), 89-98. DOI: 10.1080/014311601750038866

[13] Tyler, A. N., Svab, E., Preston, T., Présing, M., & Kovács, W. A. (2006). Remote sensing of the water quality of shallow lakes: A mixture modelling approach to quantifying phytoplankton in water characterized by high-suspended sediment. International Journal of Remote Sensing, 27(8), 1521-1537. DOI: 10.1080/01431160500419311

[14] McCullough, I. M., Loftin, C. S., & Sader, S. A. (2012). High-frequency remote monitoring of large lakes with MODIS 500m imagery. Remote Sensing of Environment, 124, 234-241. DOI: 10.1016/j.rse.2012.05.018

[15] Chawira, M., Dube, T., & Gumindoga, W. (2013). Remote sensing based water quality monitoring in Chivero and Manyame lakes of Zimbabwe. Physics and Chemistry of the Earth, Parts A/B/C, 66, 38-44. DOI: 10.1016/j.pce.2013.09.003

[16] Kutser, T., Pierson, D. C., Kallio, K. Y., Reinart, A., & Sobek, S. (2005). Mapping lake CDOM by satellite remote sensing. Remote Sensing of Environment, 94(4), 535-540. DOI: 10.1016/j.rse.2004.11.009

[17] Birkett, C. M., & Mason, I. M. (1995). A new global lakes database for a remote sensing program studying climatically sensitive large lakes. Journal of Great Lakes Research, 21(3), 307-318. DOI: 10.1016/s0380-1330(95)71041-3

[18] Birkett, C. M. (1994). Radar altimetry: a new concept in monitoring lake level changes. Eos, Transactions American Geophysical Union, 75(24), 273-275. DOI: 10.1029/94eo00944

[19] Bajracharya, S. R., Mool, P. K., & Shrestha, B. R. (2007). Impact of climate change on Himalayan glaciers and glacial lakes: case studies on GLOF and associated hazards in Nepal and Bhutan. Kathmandu: International Centre for Integrated Mountain Development.

[20] Kutser, T., Metsamaa, L., Strömbeck, N., & Vahtmäe, E. (2006). Monitoring cyanobacterial blooms by satellite remote sensing. Estuarine, Coastal and Shelf Science, 67(1), 303-312. DOI: 10.1016/j.ecss.2005.11.024

[21] Sparavigna, A. C. (2013). The Shrinking Toshka Lakes in the Google Earth Images. International Journal of Sciences, 2(August), 92-94. DOI: 10.18483/ijsci.240

[22] Sparavigna, A. C. (2011). The decreasing level of Toshka Lakes seen from space. arXiv preprint arXiv:1107.4430.

[23] Sparavigna, A. C. (2010). Merowe Dam and the Inundation of Paleochannels of the Nile. arXiv preprint arXiv:1011.4911.

[24] Sparavigna, A. C. (2010). The Merowe Dam on the Nile. Archaeogate, Article 1332. Published on 3 December 2010.

[25] Fassieh, K. M., & Zaki, M. A. (2014). A water management model for Toshka depression. Journal of Applied Mathematics, 2014. Article ID 731846. DOI: 10.1155/2014/731846

[26] Hesami, A., & Amini, A. (2016). Changes in irrigated land and agricultural water use in the Lake Urmia basin. Lake and Reservoir Management, 32(3), 288-296. DOI: 10.1080/10402381.2016.1211202

[27] Amini, A., & Hesami, A. (2017). The role of land use change on the sustainability of groundwater resources in the eastern plains of Kurdistan, Iran. Environmental Monitoring and Assessment, 189(6), 297. DOI: 10.1007/s10661-017-6014-3

[28] https://en.wikipedia.org/wiki/Aral_Sea Retrieved 8 january 2018

[29] Liston, Enjoli (2014). Satellite images show Aral Sea basin 'completely dried'. The Guardian. London: Guardian News and Media Limited.

[30] https://en.wikipedia.org/wiki/Sarygamysh_Lake Retrieved 8 january 2018

[31] Sparavigna, A. C. (2017). Image Segmentation Applied to the Study of Micrographs of Cellular Solids. International Journal of Sciences, 6(02), 68-76. DOI: 10.18483/ijSci.1201

[32] Sparavigna, A. C. (2016). A method for the segmentation of images based on thresholding and applied to vesicular textures. Philica 2016, 889. Available arXiv, http://adsabs.harvard.edu/abs/2016arXiv161201131S

[33] Sparavigna, A. C. (2017). Measuring the particles in fly ash by means of an image segmentation. Philica, n.1105. Available HAL, https://hal.archives-ouvertes.fr/hal-01579285v1

[34] Sparavigna, A. C. (2016). Analysis of a natural honeycomb by means of an image segmentation. Philica, n.897. Available HAL, https://hal.archives-ouvertes.fr/hal-01416832v1

[35] Sparavigna, A. C. (2017). Image segmentation applied to micrographs of microcellular plastics. Philica, n.953. Available HAL, https://hal.archives-ouvertes.fr/hal-01456692v1

[36] Sparavigna, A. C. (2017). Measuring the size of tubules in phloem and xylem of plants. Philica, n.1104. Available HAL, https://hal.archives-ouvertes.fr/hal-01578826v1

[37] Sparavigna, A. C. (2017). Image Segmentation Applied to the Analysis of Fabric Textures. Philica, n.1157. Available HAL, https://hal.archives-ouvertes.fr/hal-01633061v1

[38] Sparavigna, A. C. (2017). An image segmentation for the measurement of microstructures in ductile cast iron. PHILICA, n.1159. Available HAL, https://hal.archives-ouvertes.fr/hal-01635665v1

[39] Sparavigna, A. C. (2017). Measuring the blood cells by means of an image segmentation. PHILICA, Article n.1176. Available HAL, https://hal.archives-ouvertes.fr/hal-01654006/

Information about this Article
Published on Thursday 11th January, 2018 at 13:53:11.

The full citation for this Article is:
Sparavigna, A.C. (2018). Image segmentation applied to satellite imagery for monitoring water in lakes and reservoirs. *PHILICA Article number 1214*.