PROCEEDINGS OF SPIE

8th Iberoamerican Optics Meeting and 11th Latin American Meeting on Optics, Lasers, and Applications

Manuel Filipe P. C. Martins Costa
Editor

22–26 July 2013
Porto, Portugal

Sponsored by
International Commission for Optics • The Optical Society • European Optical Society • Red Iberoamericana de Óptica• Innova Scientific • Álava Ingenieros • Caixa Geral de Depósitos • Messe München GmbH (Germany) • Universidade do Porto (Portugal) • Centro de Láseres Pulsados (Spain) • LASERLAB-EUROPE • Fundação para a Ciência e a Tecnologia (Portugal) • Faculdade de Ciências da Universidade do Porto (Portugal) • FiberSensing, Sistemas Avançados de Monitorização, S.A. (Portugal) • PI miCos GmbH (Germany) • MT Brandão (Portugal) • Universidade do Minho (Portugal) • Zurich Instruments AG (Switzerland) • Sociedade Portuguesa de Física (Portugal) • APLO (Portugal) • Hands-On Science (Portugal) • La Sociedad Española de Óptica (Spain) • La Academia Mexicana de Óptica, A. C. (Mexico) • Red Colombiana de Óptica (Colombia) • Comité Venezolano De Optica (Venezuela) • La Société Tunisienne d'Optique (Tunisia) • African Laser Atomic Molecular & Optical Sciences Network • Optics and Photonics Society of Singapore (Singapore) • Photonics21 • Southern European Cluster of Photonics and Optics • LASER World of PHOTONICS (Germany) • European Photonics Industry Consortium

Technical Cosponsor and Publisher
SPIE

Volume 8785
Part One of Three Parts

Proceedings of SPIE 0277-786X, V. 8785

8th Iberoamerican Optics Meeting and 11th Latin American Meeting on Optics, Lasers, and Applications,
edited by Manuel Filipe P. C. Martins Costa, Proc. of SPIE Vol. 8785, 878501
© 2013 SPIE · CCC code: 0277-786X/13/$18 · doi: 10.1117/12.2050511

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:
Author(s), "Title of Paper," in *8th Iberoamerican Optics Meeting and 11th Latin American Meeting on Optics, Lasers, and Applications*, edited by Manuel Filipe P. C. Martins Costa, Proceedings of SPIE Vol. 8785 (SPIE, Bellingham, WA, 2013) Article CID Number.

ISSN: 0277-786X
ISBN: 9780819496010

Published by
SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIEDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B … 0Z, followed by 10-1Z, 20-2Z, etc.

The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID Number.

Illumination analysis of the digital pattern recognition system by Bessel masks and one-dimensional signatures

Solorza S.[a] and Álvarez-Borrego J.[b]

[a]Facultad de Ciencias, UABC, Km. 103, Carretera Tijuana-Ensenada, Ensenada, B.C., México, C.P. 22860;
[b]División de Física Aplicada, Departamento de Óptica, CICESE, Carretera Ensenada-Tijuana No. 3918, Fraccionamiento Zona Playitas, Ensenada, B.C., México, C.P. 22860

ABSTRACT

The effects of illumination variations in digital images are a trend topic of the pattern recognition field. The luminance information of the objects help to classify them, however the environment illumination could cause a lot of problem if the system is not illumination invariant. Some applications of this topic include image and video quality, biometrics classification, etc. In this work an illumination analysis for a digital system invariant to position and rotation based on Fourier transform, Bessel masks, one-dimensional signatures and linear correlations are presented. The digital system was tested using a reference database of 21 fossil diatoms images of gray-scale and 307 × 307 pixels. The digital system has shown an excellent performance in the classification of 60,480 problem images which have different non-homogeneous illumination.

Keywords: Image processing, pattern recognition, binary rings mask, one-dimensional signature

1. INTRODUCTION

Since the evolution of computers in the middle of last century, the pattern recognition of digital images based on correlations has been studied in science as well as technology areas. Their applications are broad and varieties.[1] The techniques developed are used to identify micro- and macro- objects, for example, diatoms fossil digital images.[2] Diatoms are one of the basic sources for the formation of organic matter in the ocean, and actively participate in sedimentation, not only during recent periods of time but through the remote past. The presence of diatom valves in marine paleoenvironments has been used for the study of climatic changes as well as geomorphological processes;[3] hence the fast and proper classification of diatoms has environmental and economic impact.

In this work is presented a pattern recognition digital system invariant to position, rotation, noise and illumination. The digital system has shown an excellent performance, a confidence level of 100% in the identification of 60,480 problem images, even they are presented non-homogeneous illumination.

The material of this work is organized as follows: in section 2, the Bessel mask and one-dimensional signature construction procedures are explained. Section 3 presents the pattern recognition methodology. Section 4 shows the statistical analysis tests. Finally, in Section 6 the conclusions are given.

Further author information: (Send correspondence to S. Solorza)
S. Solorza.: E-mail: selene.solorza@uabc.edu.mx, Telephone: +52 (646) 1744560
J. Álvarez-Borrego: E-mail: josue@cicese.mx, Telephone: +52 (646)1750500

8th Iberoamerican Optics Meeting and 11th Latin American Meeting on Optics, Lasers, and Applications,
edited by Manuel Filipe P. C. Martins Costa, Proc. of SPIE Vol. 8785, 878573

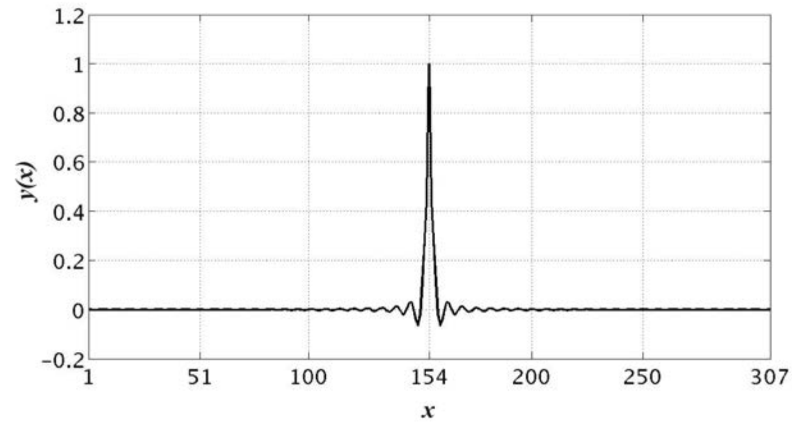


Figure 1. The graph of Equation (2).

2. THE DIGITAL SYSTEM

The digital system works with $n \times n$ gray-scale images, only. For a given image I, (x, y) represents a pixel of the image and $I(x, y)$ its corresponding intensity value, $x, y \in 1, \ldots, n$ and the centered-pixel (c_x, c_x) of the image is given by

$$c_x = \begin{cases} \frac{n}{2} + 1, & \text{if } n \text{ is even,} \\ \lfloor \frac{n}{2} \rfloor + 1, & \text{if } n \text{ is odd,} \end{cases} \tag{1}$$

here $\lfloor z \rfloor$ rounds z to the nearest integer towards $-\infty$. The shift invariance is achieved in an easy manner by the modulus of the Fourier transform of the image, that is, $|FT(I)|$.

2.1 The Bessel Mask

To obtain the rotational invariance, a binary rings mask is build using the ratio of the Bessel function of first kind and first order by its argument, that is

$$y(x) = \begin{cases} \frac{J_1(x-c_x)}{x-c_x}, & \text{if } x \neq c_x, \\ 1, & \text{if } x = c_x, \end{cases} \tag{2}$$

where $x = 1, \ldots, n$. Fig. 1 shows the graph of Equation (2) with $n = 307$, thus $c_x = 154$. Base on Equation (2) we can build the following binary function

$$Z(x) = \begin{cases} 1, & \text{si } y(x) > 0, \\ 0, & \text{si } y(x) \leq 0. \end{cases} \tag{3}$$

The function in Equation (3) is symmetric by construction, then for clarity in Fig. 2 it is shown only that values of the function $Z(x)$ such that $x \geq c_x$. Finally, taking the vertical axis $x = c_x$ as the rotation axis, the graphs is rotated 360 degrees to obtain concentric cylinders of height one, different widths and centered in (c_x, c_x) pixel. Mapping those cylinders in the Cartesian-plane we built the Bessel binary rings mask (Fig. 3c).[2,4]

2.2 The Signature of the Image

The first step to obtain the one-dimensional signatures, it is filter the $|FT(I)|$ (Fig. 3b) by the Bessel mask, hereafter named B (Fig. 3c), that is,

$$H = B * |FT(I)|. \tag{4}$$

Fig. 3d shows the H image for Fig. 3a. After that, the rings in H are numbered from the center toward out-side to get the set

$$index = \{ring\ index \in \bar{n}\}, \tag{5}$$

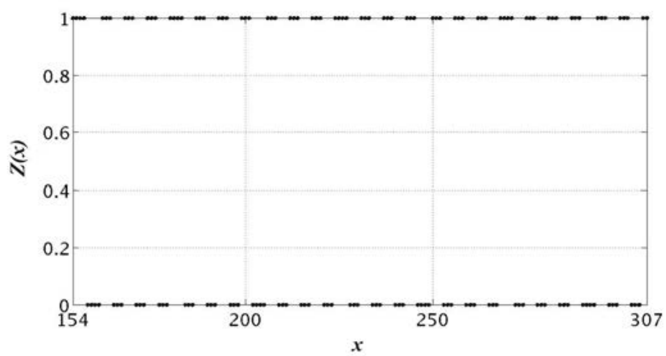


Figure 2. The binary function.

where $\bar{n} = 1, \ldots, n$. The rings in each image are numbered from the center toward out-side and the addition of the intensity values in each ring are computed to generate the function

$$\begin{aligned} signature &= index \to A \subset \mathbb{R}, \\ signature(ring) &= \sum H, \text{ if } H(x,y) \text{ belongs to } ring. \end{aligned} \tag{6}$$

Because always the cardinality of A is bigger than one, the function *signature* is called one-dimensional signature of the image I. When the cardinality of A is one, then we have a scalar signature of I. Fig. 3e shows the one-dimensional signature associated to Fig. 3a.

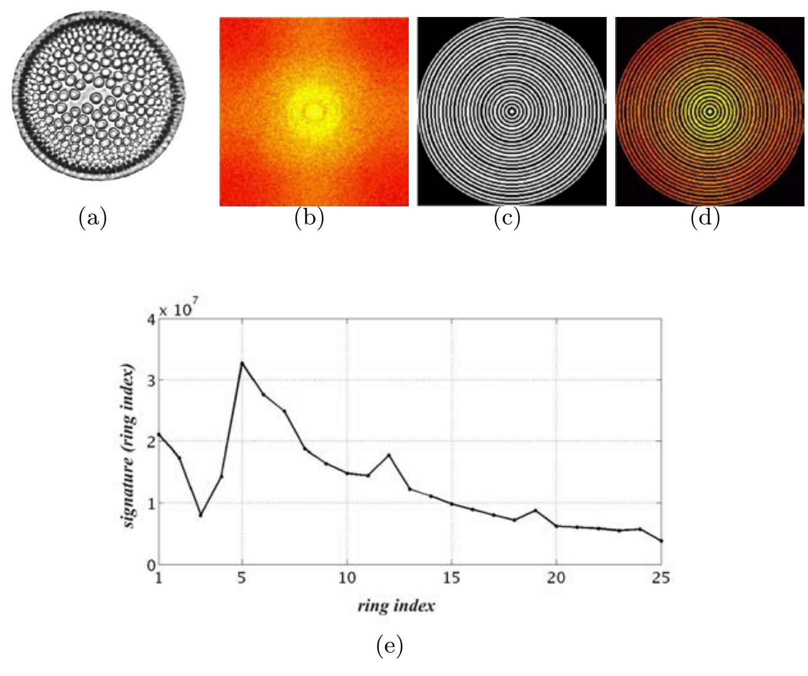


Figure 3. The signature procedure example. (a) $I(x,y)$: *Actinocyclus ingens - Rattray.* (b) $|FT(I)|$. (c) B: Bessel mask. (d) $H = B * |FT(I)|$. (e) Signature of Fig. 3a.

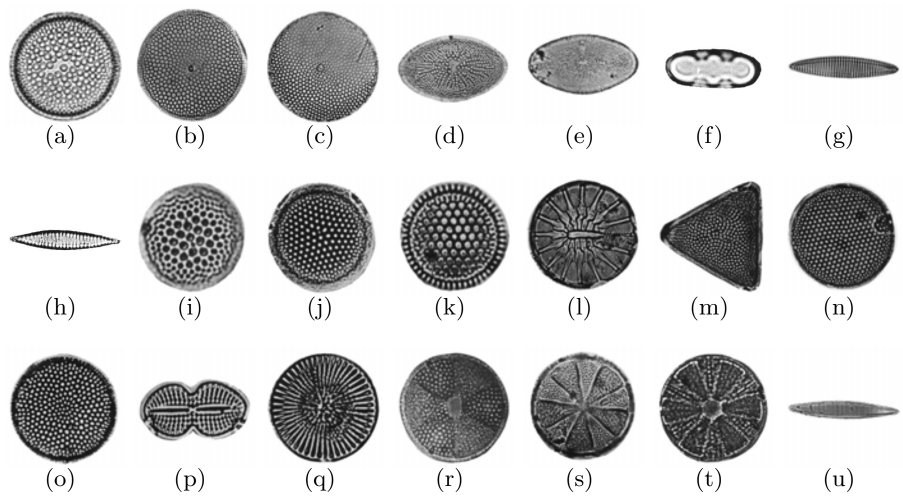


Figure 4. Diatoms fossil digital images. (a) A: *Actinocyclus ingens - Rattray.* (b) B: *Azpeitia sp.* (c) C: *Azpeitia nodulifera - (Schmidth) Fryxell et Sims.* (d) D: *Actinocyclus ellipticus - Grunow in van Heurck.* (e) E: *Actinocyclus ellipticus var moronensis - (Deby ex Rattray) Kolbe.* (f) F: *Denticulopsis praedimorpha - Barron ex Akiba.* (g) G: *Nitzchia praereinholdii - Schrader.* (h) H: *Bogorovia praepaleacea - (Schrader) Jouse.* (i) I: *Thalassiosira oestruppii var 1.* (j) J: *Thalassiosira oestruppii var 2.* (k) K: *Thalassiosira domifacta - (Hendey) Jouse.* (l) L: *Asteromphalus imbricatus - Wallich.* (m) M: *Pseudotriceratium cinnamomeum - (Greville) Grunow.* (n) N: *Thalassiosira kozlovii - Makarova.* (o) O: *Coscinodiscus radiatus - Ehrenberg.* (p) P: *Diploneis bombus - Cleve-Euler in Backman et Cleve-Euler.* (q) Q: *Stephanodiscus sp.* (r) R: *Actinoptychus undulatus - (Bailey) Ralf.* (s) S: *Actinoptychus bipunctatus - Lohman.* (t) T: *Actinoptychus splendens - (Shadbolt) Ralf ex Pritchard.* (u) U: *Nitzschia reinholdii - Kanaya emend Barron & Baldauf.*

3. PATTERN RECOGNITION

In the recognition step, first of all, it is set the signatures for the target T, called S_T. Then, the autocorrelation of S_T is computed as

$$C_L(S_T) = FT^{-1}\left\{|FT(S_T)|\, e^{i\varphi}\, |FT(S_T)|\, e^{-i\varphi}\right\}, \tag{7}$$

where φ is the phase of the Fourier transform of the signature S_T. The $max\left\{|C_L(S_T)|\right\}$ will determine if a problem image PI is T or other image.

To determine the pattern in PI, as a first step its signature is obtain, lets call it S_P. The next step is compute the correlation of S_T and S_P as

$$C_L(S_T, S_P) = FT^{-1}\left\{|FT(S_P)|\, e^{i\phi}\, |FT(S_T)|\, e^{-i\varphi}\right\}, \tag{8}$$

here ϕ is the phase of the Fourier transform of the signature S_P. If $max\left\{|C_L(S_T, S_P)|\right\}$ value is similar to the value associated to S_T, hence the problem image contains the target, otherwise there is an object different to the target.

4. RESULTS

The digital system invariant to position, rotation, noise and illumination was tested using the 307×307 gray-scale diatom digital images in Fig. 4. Each image was selected as target, thus the target database has twenty-one elements. The target images were rotated 360 degrees, one by one, hence in the problem images database we worked with $7,560$ images. The saw tooth effect (noise) is incorporated into the problem due to the rotation of the images, therefore the digital system is more robust in the pattern recognition. Finally, each problem image was altered with eight different types of non-homogeneous illuminations as in Fig. 5, thus the system were proved with $60,480$ problem images with non-homogeneous illumination.

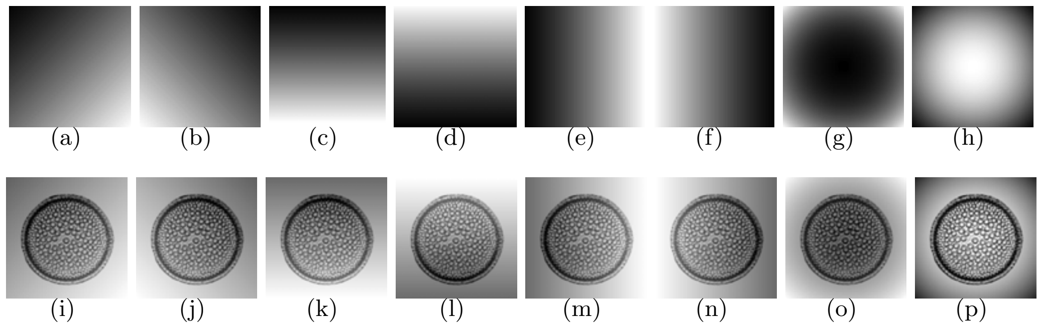


Figure 5. Problem image altered with eight different non-homogeneous illumination.

The maximum values of the magnitude for the correlations were box plotting using the mean of those values with two standard errors (±2SE) and outliers. Fig. 6a shows an example of a box plot when the diatom A is the target, as we can see there is not an overlap of the whiskers (Fig. 6b), hence we conclude that the system has a confidence level of 100% to identify diatoms A. However, the system using diatom R as target will name erroneously some diatoms A as R (Fig. 6d), fortunately the correlation function is non-commutative hence diatoms A are classified without mistakes, then all images that the system classified as diatoms R, it will be tested again but using the diatom A as the target, hence the system will identify without doubts the diatoms A and the rest are diatoms R, therefore the complete identification is done, but will be used more computational-time, only. The same idea works for the other cases presented in Table 1. Therefore, we have a digital system that classifies properly all diatom images.

Table 1. Confidence level (in %) of the digital system by Bessel mask tested with non-homogeneous illumination problem images.

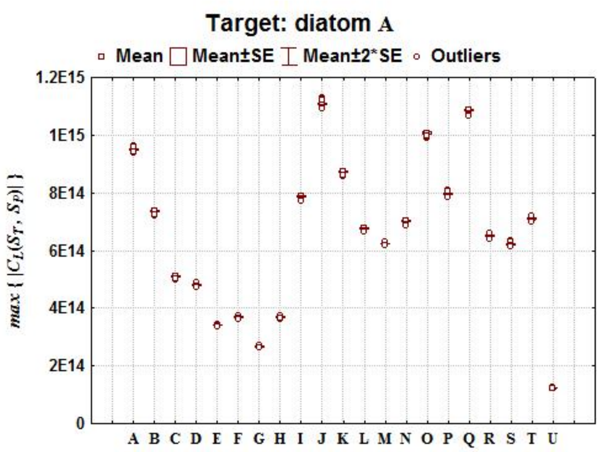
diatom	confidence level	diatom	confidence level	diatom	confidence level
A	100	H	100	O	100
B	100	I	95.4 due to K, Q	P	95.4 due to I
C	100	J	100	Q	100
D	100	K	95.4 due to Q	R	100 without A
E	100 without K	L	95.4 due to T	S	100 without K
F	100	M	100	T	100
G	100	N	100	U	95.4 due to R

5. CONCLUSIONS

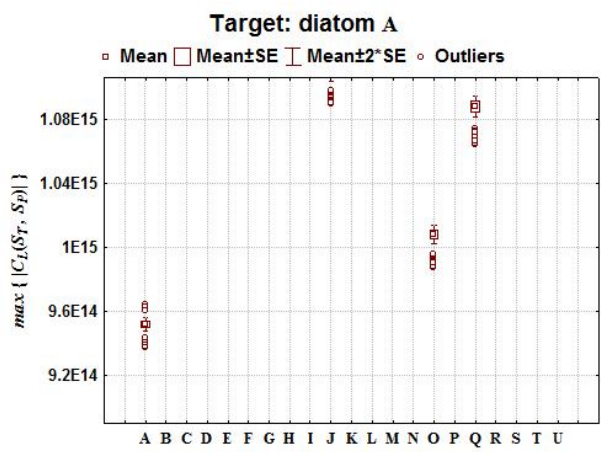
The recognition pattern digital system was tested using twenty-one gray-scale diatom fossil digital images as target and 60,480 problem images with non-homogeneous illumination. The statistical analysis were done by box plots with mean, two standard errors (±2SE) and outliers. The digital system has shown an excellent performance in the recognition of the diatom fossil images even with non-homogeneous illumination.

ACKNOWLEDGMENTS

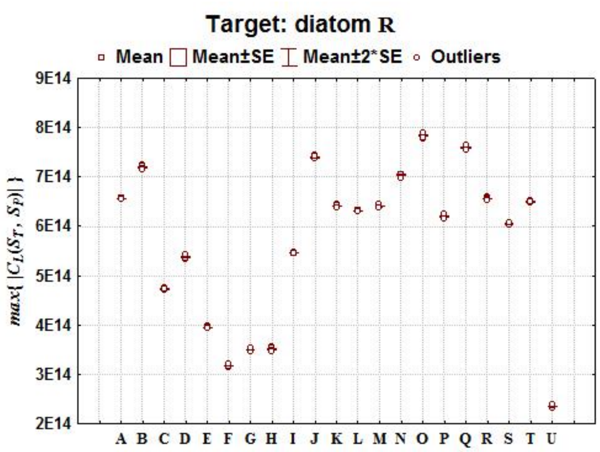
This work was partially supported by CONACyT under grant No. 102007 and 169174.



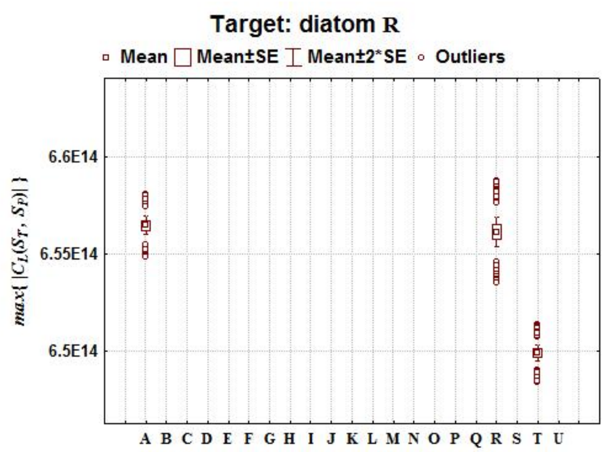
(a)



(b)



(c)



(d)

Figure 6. (a) Statistic analysis using target A. (b) Amplification around the zone of target A. (c) Statistic analysis using target R. (d) Amplification around the zone of target R.

REFERENCES

[1] R. C. Gonzalez R. E. Woods and S. L. Eddins, *Digital image processing using Matlab*, Tata McGraw Hill Education Private Limited, 2010 (second edition).

[2] J. Álvarez-Borrego and S. Solorza, "Comparative analysis of several digital methods to recognize diatoms," *Hidrobiologica* **20**, pp. 158–170, 2010.

[3] M. Hajós, "Upper eocene and lower oligocene diatomaceae, archaemonadaceae and silicoflagellates in southwestern pacific sediments," *DSSP, leg 29. Initial reports DSPP.* **5**, pp. 817–883, 1976.

[4] J. Álvarez-Borrego, S. Solorza and M. A. Bueno-Ibarra, "Invariant correlation to position and rotation using a binary mask applied to binary and gray images," *Opt. Comm.* **294**, pp. 105–117, 2013.