Scientific Profile

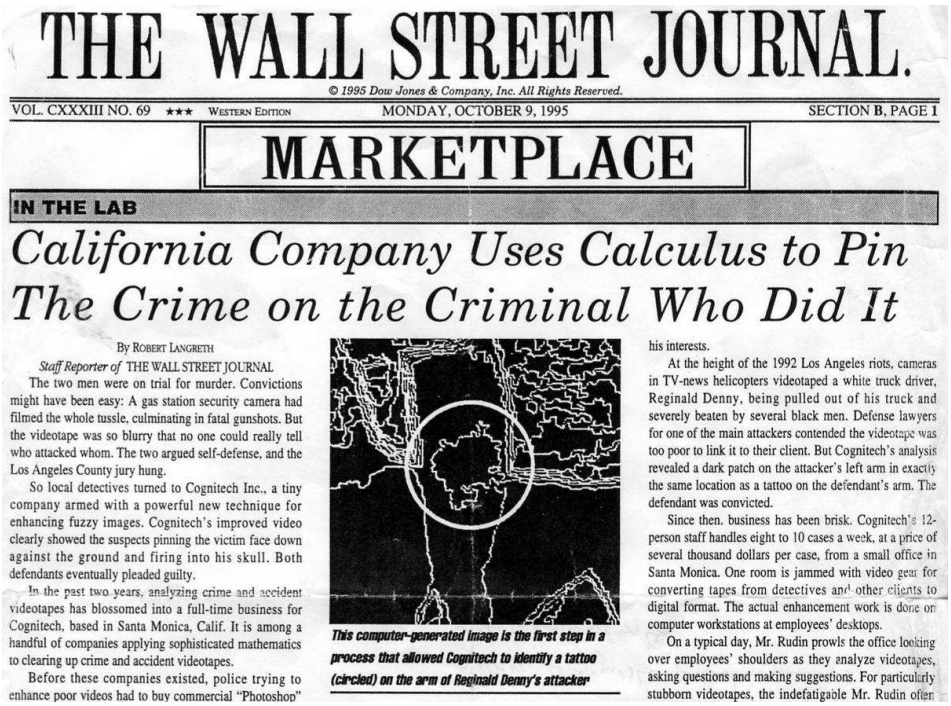
Jean-Michel Morel (JMM) is a mathematician who trained in partial differential equations, variational models and nonlinear analysis with Haïm Brezis. In 1989, impressed by the methods and discoveries of David Mumford and Yves Meyer, he started working on image processing.

This mathematical modeling method reexamines theories and algorithms of image science. It sifts their many variants by a mathematical analysis, and tries to deduce the right algorithms. The payoff can be huge. Imaging science discoveries often end up in a Babel tower of algorithms and variants with non reproducible results. JMM is generally acknowledged to have clarified by an axiomatic method the role of partial differential equations in image processing in three seminal papers with Alvarez, Catté, Coll, Guichard and Lions. They cumulate about 2500 citations in Google Scholar.

JMM has contributed to the mathematical elaboration and the algorithms of *four central questions in image analysis and image processing: image segmentation, image denoising, image invariant matching,* and the faultless feature detection in images with *false alarm control*. In 1995, the image segmentation algorithm discovered by JMM and his collaborators Georges Koepfler and Sergio Solimini, was the *first image processing algorithm used and validated in a US criminal court* during the LA riot trials. The segmentation result, obtained by JMM's collaborator Lenny Rudin, CEO of Cognitech, was published on first page (Section B) of Wall Street Journal, October 9, 1995 This algorithm was described in JMM and Solimini's 1994 book. The book reviewed all existing image segmentation algorithms (more than 300) and checked that they were all discrete variants of the 1989 proposed Mumford-Shah segmentation theory. In continuation, this book provides a first complete mathematical analysis (existence, partial regularity) of optimal segmentation.

Most applicative breakthroughs of JMM's team and its mathematical method are recent, though. In 2005, JMM and his collaborators defined a new kind of mathematical process for image denoising, *"nonlocal means"*. This method has received three international best paper awards and has become *immediately accessible to photographers worldwide* thanks to the DxO Labs company (google request: "DxO Optics"). Five year later the state of the art denoising methods (NL-means-PCA, BM3D, KSVD,...) are based on the patch comparison principle introduced in NL-means. In 2008, a fully affine invariant image comparison method, ASIFT, has been discovered by JMM and Guoshen Yu. This method is the most visited article of the new on line journal founded in 2009 by Jean-Michel Morel and his collaborators, *Image Processing on Line*. Its archive displays some 8000 online experiments.

In the past ten years, the author and his team have developed a *statistical theory adapted to image processing*, which permits to devise *parameter-free algorithms*. See the *on-line line segment detector* at IPOL http://www.ipol.im/). This theory is the object of *two recent monographs* by JMM and his collaborators.



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MARKETPLACE

IN THE LAB

California Company Uses Calculus to Pin The Crime on the Criminal Who Did It

By ROBERT LANGRETH

Staff Reporter of THE WALL STREET JOURNAL

The two men were on trial for murder. Convictions might have been easy: A gas station security camera had filmed the whole tussle, culminating in fatal gunshots. But the videotape was so blurry that no one could really tell who attacked whom. The two argued self-defense, and the Los Angeles County jury hung.

So local detectives turned to Cognitech Inc., a tiny company armed with a powerful new technique for enhancing fuzzy images. Cognitech's improved video clearly showed the suspects pinning the victim face down against the ground and firing into his skull. Both defendants eventually pleaded guilty.

In the past two years, analyzing crime and accident videotapes has blossomed into a full-time business for Cognitech, based in Santa Monica, Calif. It is among a handful of companies applying sophisticated mathematics to clearing up crime and accident videotapes.

Before these companies existed, police trying to enhance poor videos had to buy commercial "Photoshop"

This computer-generated image is the first step in a process that allowed Cognitech to identify a tattoo (circled) on the arm of Reginald Denny's attacker

his interests.

At the height of the 1992 Los Angeles riots, cameras in TV-news helicopters videotaped a white truck driver, Reginald Denny, being pulled out of his truck and severely beaten by several black men. Defense lawyers for one of the main attackers contended the videotape was too poor to link it to their client. But Cognitech's analysis revealed a dark patch on the attacker's left arm in exactly the same location as a tattoo on the defendant's arm. The defendant was convicted.

Since then, business has been brisk. Cognitech's 12-person staff handles eight to 10 cases a week, at a price of several thousand dollars per case, from a small office in Santa Monica. One room is jammed with video gear for converting tapes from detectives and other clients to digital format. The actual enhancement work is done on computer workstations at employees' desktops.

On a typical day, Mr. Rudin prowls the office looking over employees' shoulders as they analyze videotapes, asking questions and making suggestions. For particularly stubborn videotapes, the indefatigable Mr. Rudin often

JMM is dedicated to the training of young researchers. He has had 36 PhD students, advises currently 8 graduate students and five post-docs. Notably, *all* of his former students have become academics or industrial researchers.

JMM leads currently four main image processing projects.

The principal one, "The Twelve Labors of Image processing" founded by an ERC advanced grant, aims at publishing on line all major image processing and image analysis algorithms, past and present, to establish a reliable state of the art in these disciplines. This project has immediately evolved into a new concept of scientific journal, IPOL (*Image Processing on Line,* http://www.ipol.im/). The role of its scientific committee is to evaluate the submitted algorithms and associated codes and to guarantee their mutual consistency. In that way a certified implementation is obtained for each image processing discovery. The on line execution of the algorithms makes them immediately available and testable worldwide to all specialists. Thus the role of this new sort of journal is to foster experiments sharing and fast diffusion of algorithms. At the end of 2010 there were 16 online demos and 20 were in preparation. Each article had an archive displaying all online experiments made by IPOL visitors. In 18 months of existence, there had been 19000 online experiments made by approximately 4000 different users. Everything indicates that this new publication mode reaches much faster a significantly broader public.

The second permanent project is a collaboration on all aspects of image processing with the DxO company, world leader in image restoration software for professional photographers.

The third project, whose code name for CNES (Centre National d'Etudes Spatiales, French space agency) is MISS, is a new Earth observation satellite concept, which will produce two consecutive sweeps of each observed area with slightly dif-

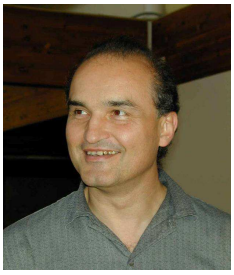
ferent angles, and will therefore deliver a stereo pair permitting to directly "see the ground in 3D". JMM's team is in charge of the image processing satellite specification and of the automatic chain that will automatically calculate the 30 centimeters accurate urban 3D elevation models.

The fourth ongoing project is the conception of a passive 3D triangulation scanner with a resolution that will be equivalent to the best active sensors (1/40000 radians angular precision). The project aims at a camera calibration accuracy boost by a 100 factor by a mathematical non parametric formalization coupled with highly accurate image processing techniques.

JMM's team receives since 1998 a permanent grant from the Office of Naval Research (US) for its contribution to the formalization of image analysis.

JMM is since 2010 a senior member of Institut Universitaire de France. He has received five national awards (three of them patronized by the French Academy of Science) and six international awards and honors. The last ones are a Clay Senior Scholarship at the Park City Mathematics Institute, 2010 (Award delivered by the Clay Mathematics Institute), and an "ovation" at ICIAM 2011 (the main international applied maths conference) for the selection in SIGEST of the SIAM paper "A review of denoising algorithms, with a new one".

1 Curriculum Vitae



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Professor of Applied Mathematics
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Career
1973-77 ENS Cachan and Universities of Orsay, and P. et M. Curie.
1980 PhD University P. et M. Curie. Adviser : Haïm Brezis
1978-84 : Assistant Professor, University of Marseille-Luminy
1984-90 Assistant Professor, University Paris-Dauphine
1985 Thèse d'Etat at University P. et M. Curie. Adviser : Haïm Brezis
1991-97 Professor at University Paris Dauphine
1997-present Professor at ENS Cachan

Awards, honors
1991 Prix de Mathématiques Philip Morris
1992 Prix CISI-ingéniérie de Mathématiques appliquées
1992 : elected junior member of Institut Universitaire de France
1996 : Prix Science et Défense
1998 : ICIP best student paper in coll. with S. Masnou
2001 : Professeur de classe exceptionnelle
2005 : CVPR best student paper in coll. A. Buadès and Tomeu Coll
2005 : ICASSP best paper award in coll. with A. Buadès and Tomeu Coll

2008 : Plenary invited Conference at SIAM Annual Conf., San Diego
2010: Clay Senior Scholar at the Summer PCMI, award funded by the Clay Mathematics Institute.
2002- : ISI list of highly cited mathematicians (http://isihighlycited.com/)
2010: Elected senior member of Institut Universitaire de France
2011: "Ovation" at ICIAM 2011 (International Conference on Industrial and Applied Mathematics) on the occasion of the selection paper in SIGEST of the paper *A review of denoising methods, with a new one.*
2002-present : ISI list of highly cited scientists (http://isihighlycited.com/).

(Current) editorial boards
Lectures Notes in Mathematics (LNM Springer, 2000-present)
Journal of Mathematical Imaging and Vision (1997-present)
SIAM Multiscale Modeling in Applied Science, 2002-2010
IFB (European Journal of Interfaces and Boundaries, 2002-present)
SIMS (SIAM journal on Imaging Science, 2007-present)
IPI (Inverse Problems and Imaging, 2007-present)
COCV (2008-present)
IJCV (International Journal of Computer Vision, 2009-present)
IPOL (Image Processing on Line, founder and coordinating editor, 2009-present)

Former PhD students (34) and what happened to them
(RD= research director, AP=associate professor, R= researcher, RE=Research Engineer, RD=Senior Researcher (Research Director))
France : Jacques Froment (Pr), Francoise Dibos (Pr), Georges Koepfler (AP), Antonin Chambolle (RD), Christian Lopez (AP), Frédéric Guichard (RD), Thierry Cohignac (RE), Lionel Moisan (Pr), Frédéric Cao (RD), Yann Gousseau (AP), Simon Masnou (AP), Denis Pasquignon (AP), Agnès Desolneux (R), François Malgouyres (AP), Pascal Monasse (R), Andrès Almansa (R), Pablo Musé (AP), Frédéric Sur (R), Julie Delon (R), Saïd Ladjal (AP), Giuseppe Devillanova (AP), Marc Bernot (RE), Jérémie Jakubowicz (R), Jean-Pascal Jacob (postdoc Hôpitaux de Genêve), Bruno Galerne (postdoc), Rafael Grompone (ERC postdoc), Neus Sabater (Caltech, postdoc), Julie Digne (ERC postdoc, Sophia and Catech), Adina Ciomaga (postdoc, Chicago)
Spain: Manolo Gonzalez (Pr), Catalina Sbert (AP), Coloma Ballester (AP), José Luis Lisani (AP), Julio Esclarin (Pr), Toni Buadès Capo (R), Ana Belen Petro (AP)

Other senior researchers that trained with JMM on image processing : Luis Alvarez (Pr), Tomeu Coll (Pr), Vicent Caselles (Pr).
Current PhD students : Yohann Tendero, Ives Rey Otero, Zhongwei Tang, Nicolas Limare, Miguel Colom, José Lezama.
PhDs coadvised with UCLA (Andrea Bertozzi): Alex Chen, Yifei Lou (postdoc, USC). With UPC Barcelona (Ph. Salembier): Mariella Dimicoli (postdoc, Collège de France).

Main funding sources
-CNES (Centre National d'Etudes Spatiales): since 1995, permanent association funded by renewable research contracts : on average 250000 €/year. During this

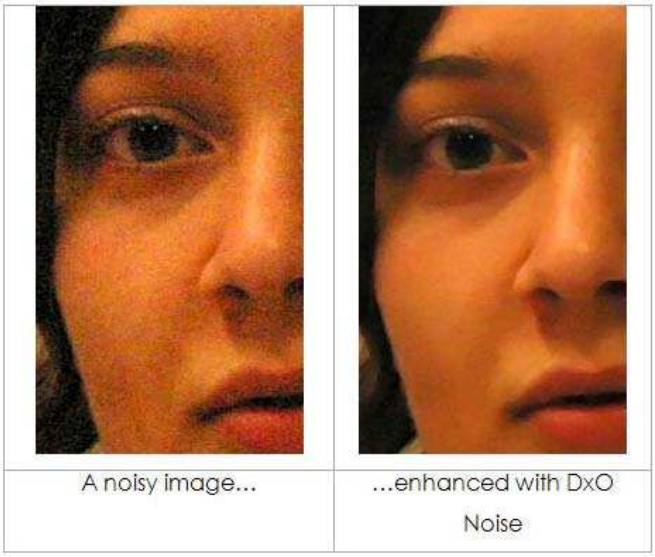

Figure 1: The renown DxO Labs company has chosen NL-means, the image denoising method invented by the PI and his team (see DxO press book).

association, JMM's team has contributed to the image processing line for the Earth Observation satellites SPOT5, Pléïades, and currently CSO.
-DxO, French company specialized in image processing : permanent contract since 2007 : 60000 €/year.
-Office of Naval Research (US Navy): permanent grant, renewed since 1997: 120000 US dollars/year. This grant is given to the team for its development of a rigorous theory of image analysis.
-European Research Council, advanced grant: 2010-2014, 360000€/year

Ten most significant papers 2000-2010

(Google scholar citation numbers: December 2010)
• J.M. Morel and G. Yu, ASIFT: A new framework for fully affine invariant image comparison. SIAM Journal on Imaging Science, 2(2), 438-469, 2009, cited by 45.
• A. Buades, B. Coll, and J.M. Morel. A Review of Image Denoising Algorithms, with a New One. *Multiscale Modeling and Simulation*, 4(2):490, 2005, cited by 532,
• A. Desolneux, L. Moisan, and J.M. Morel. Meaningful Alignments. *International Journal of Computer Vision*, 40(1):7–23, 2000. cited by 108,
• A. Desolneux, L. Moisan, and J.M. Morel. Edge Detection by Helmholtz Principle. *Journal of Mathematical Imaging and Vision*, 14(3):271–284, 2001. cited by 110,
• T. Buades, B. Coll, and J.M. Morel. Nonlocal image and movie denoising. *Int. J. of Computer Vision*, 76(2):123–139, 2008. cited by 102,
• A. Desolneux, L. Moisan, and J.M. Morel. A Grouping Principle and Four Applications. *IEEE Trans. on Pattern Anal. and Machine Intel.*, pages 508–513, 2003, cited by 94,
• Y. Gousseau and J.M. Morel. Are Natural Images of Bounded Variation? *SIAM Journal on Mathematical Analysis*, 33:634, 2001. cited by 61,
• A. Desolneux, L. Moisan, and J.M. Morel. Maximal meaningful events and applications to image analysis. *Annals of Statistics*, 31(6):1822–1851, 2003. cited by 50,

• L. Ambrosio, V. Caselles, S. Masnou, and J.M. Morel. Connected components of sets of finite perimeter and applications to image processing. *J. of the European Math. Soc.*, 3(1):39–92, 2001. cited by 57.

Three monographs 2000-2010

• A. Desolneux, L. Moisan, and J.M. Morel. *From Gestalt Theory to Image Analysis: A Probabilistic Approach.* Springer, 2008, cited by 74.
• M. Bernot, V. Caselles, and J.M. Morel. *Optimal Transportation Networks: Models and Theory.* Springer, 2009, cited by 28.
• F. Cao, J.L. Lisani, J.M. Morel, P. Muse, and F. Sur. *A Theory of Shape Identification.* Springer Verlag, 2008, cited by 22.

Four Patents 2000-2010

1-A. Buades, B. Coll, J.M Morel, "Procédé de traitement des données d'image, par réduction de bruit d'image, et caméra intégrant de moyens de mise en oeuvre du procédé". Issued by INPI, 02/07/2007. European Patent application pending PCT/FR2005/000897. Licensing agreements negotiated with: DxO (French company), LIM (Czech company), Cognitech (US company).
2- Rudin, Leonid I., Lisani, Jose Luis, Morel, Jean Michel, Yu, P. Owned by Cognitech, Inc. Video demultiplexing based on meaningful modes extraction United States Patent 7328198, 02/05/2008.
3- Rouge, Bernard, Morel, Jean-Michel, "Image acquisition by push-broom scanning ", owned by CNES : US Patent 6493021, Issued on 12/10/2002.
4- Jean-Michel Morel et Guoshen Yu, Procédé et dispositif de reconnaissance invariante-affine de formes, filed n° 0853244, 1000030240, 19/05/2008, issued by INPI December 31, 2010, US, PCT, Japan, etc. pending.

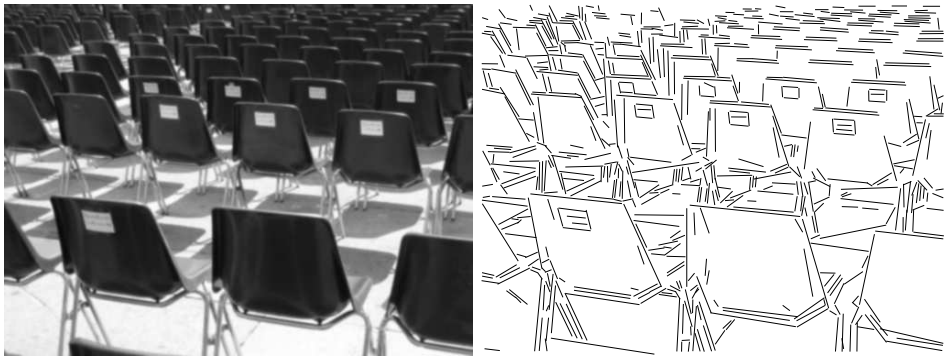

Figure 2: Result of the zero parameter line segment detector, image with strong perspective. See on line demo LSD: a Line Segment Detector at http://www.ipol.im/.