Multidisciplinary Engineering Education: Preparing Professionals for the Betterment of Humanity

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Why Be an Engineer?

Engineers are

- Highly educated
- Knowledgeable, Intelligent
- Smart, Talented
- Innovative
- Creative
- Problem solvers
- Entrepreneurs
- Always in demand and paid well!

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… But it is Not Easy!

Engineering is

- Vast
- Evolving
- Expanding
- Demanding
- Rapidly changing
- Getting more complex
- Perpetually challenging!

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The Expanding Domains of Engineering

- From Civil to Geomatics, Structural, and Transportation Engineering
- From Electrical to Power Systems, Nuclear Engineering, Electronics, Communication, Computers, Robotics, Photonics, and Informatics
- From Mechanical to Automotive, Manufacturing, Production, Mechatronics, Systems, and Industrial Engineering
- From Chemical to Petroleum, Oil & Gas, Pipeline, Mining, and Geological Engineering … and more!

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Emerging and Far-reaching Fields of Engineering

- Biomedical to Neural Engineering
- Agricultural to Food & Nutrition Engineering
- Genetic to Tissue Engineering
- Environmental to Sustainable Engineering
- Aeronautics to Astronautics & Space Engineering
- Marine to Oceanic Engineering
- Textile to Fashion Engineering … and more!

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Essentials of Engineering

- Scientific investigation and experimentation: Quantitative and objective analysis
- Mathematical modeling
- Knowledge of materials
- Design of devices, systems, and processes
- Synthesis
- Project management
- Solutions to practical and real-life problems
- Innovation and creativity

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Skill Set of a Successful Engineer

- Advanced knowledge in the chosen area
- Curiosity and intense desire to learn more
- Persistence and perseverance: willingness to accept a negative outcome and move on
- Being open for collaborative team work: being a part of the whole
- Honesty, integrity, and mutual trust
- Openness and broad framework of thinking
- Problem-solving techniques
- Professionalism: ethics, accountability, and equity
- Communication skills

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Be Multilingual!

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The Multidisciplinary Field of Biomedical Engineering

- From bridges to artificial ligaments
- From electrical power plants to cardiac pacemakers
- From railway engines to prosthetic limbs
- From chemical and petroleum plants to artificial tissues and organs
- From computers to lab-on-a-chip and control systems to manage diabetes and other diseases
- From communication and control systems to computer-aided diagnosis

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Broad Background Required for Biomedical Engineering

- Physics and Chemistry
- Mathematics and Statistics
- Biology, Anatomy, Physiology, and Pathology
- Biochemistry
- Material Science
- Sensors and Instrumentation
- Engineering Principles
- Medical Diagnosis and Therapy
- Information Processing and Analysis
- Multidisciplinary Preparation!

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...and for Computer-aided Diagnosis and Therapy

- Biomedical Engineering and Medical Physics
- Diagnostic Medical Imaging and Radiology
- Digital Signal and Image Processing
- Statistical Analysis and Pattern Recognition
- Estimation, Modeling, Prediction, and Detection of Events
- Computer Vision
- Computer and Software Engineering
- Information and Communication Technology
- Biomedical Signal and Image Analysis
- Control Systems and Diagnostic Decision Making

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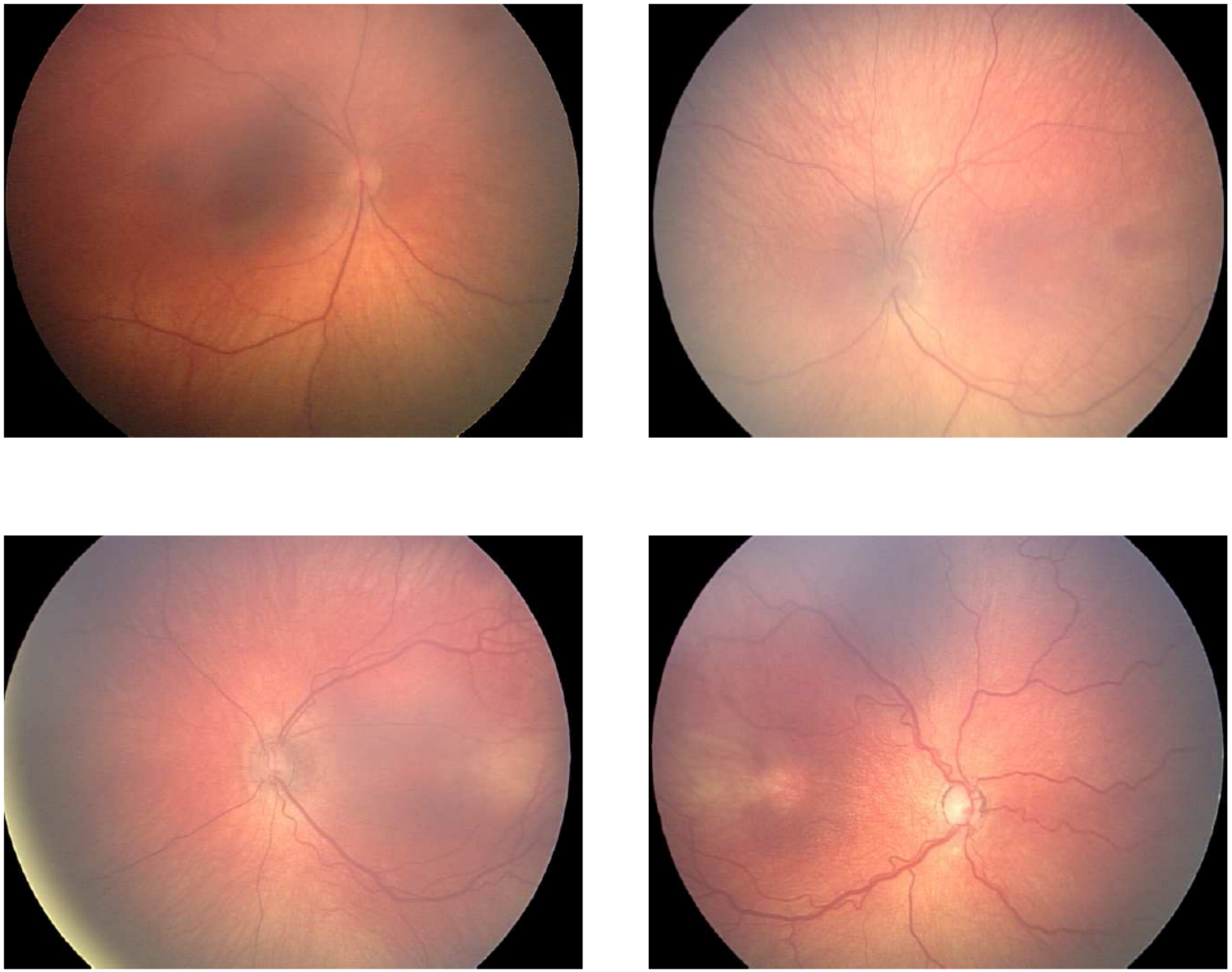
Computer-aided Diagnosis of Retinopathy of Prematurity



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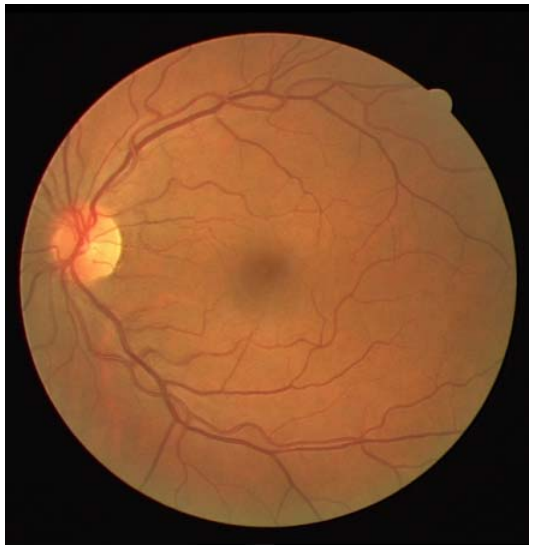
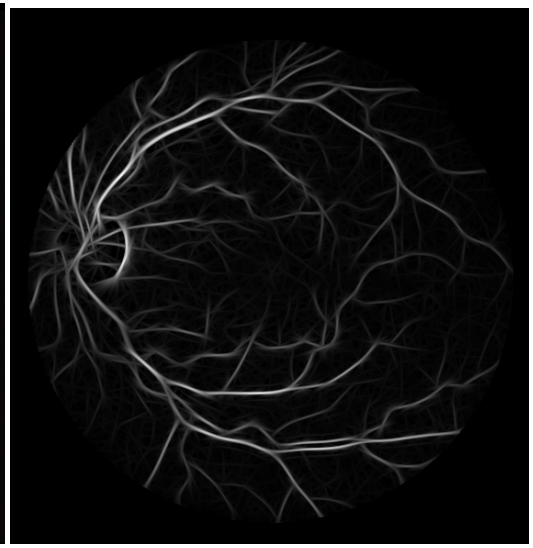
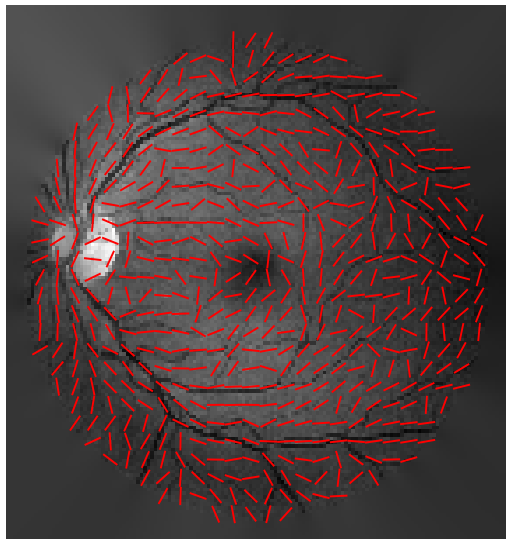
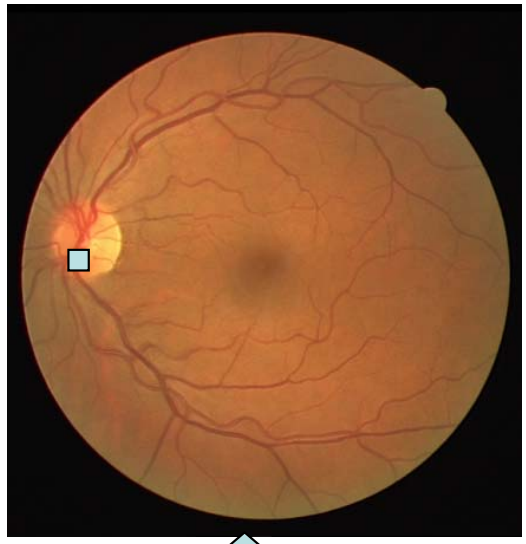
$$g(x,y)=\frac{1}{2\pi\sigma_x\sigma_y}\exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right]\cos(2\pi f x)$$

$$\vec{v}(x,y)=\begin{pmatrix}v_x\\v_y\end{pmatrix}=\mathbf{A}\begin{pmatrix}x\\y\end{pmatrix}+\mathbf{b},\qquad \mathbf{A}=\begin{bmatrix}a & b\\ b & c\end{bmatrix},\quad \mathbf{b}=\begin{bmatrix}d\\ e\end{bmatrix}$$

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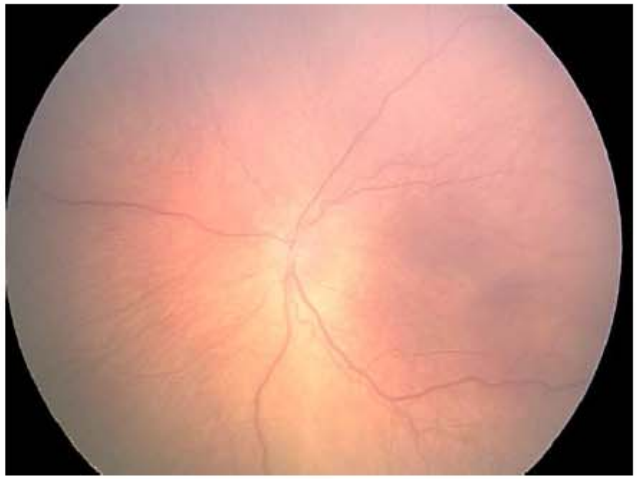
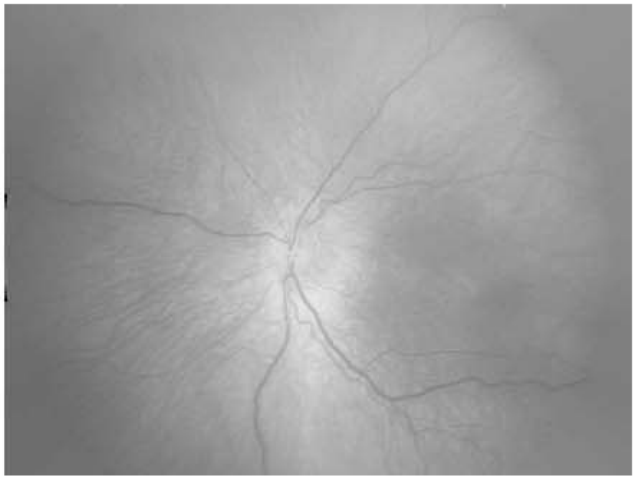
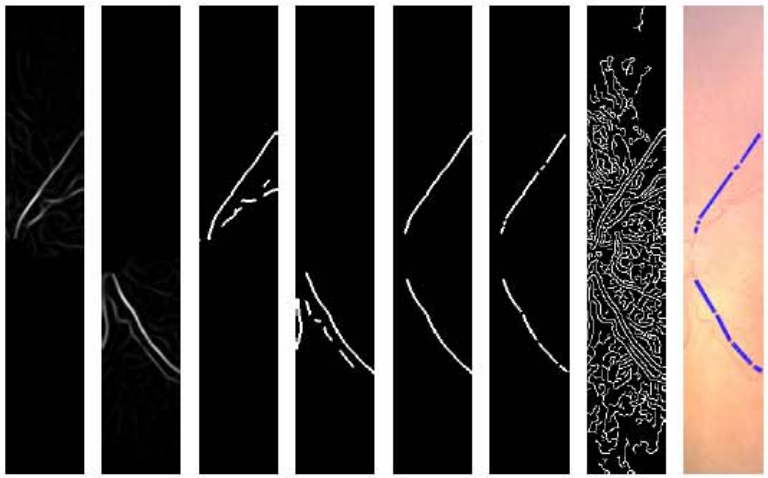
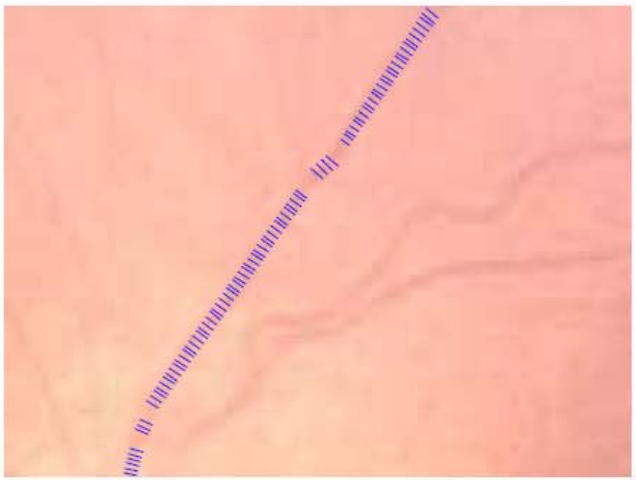
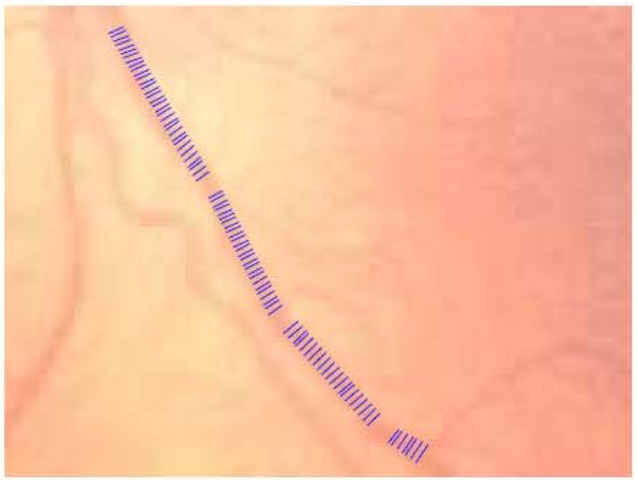
Major Temporal Arcade Width: No Plus Disease 111 ± 18 µm



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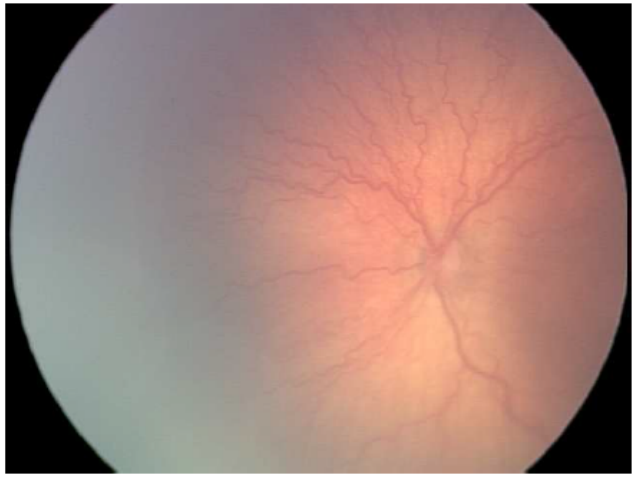
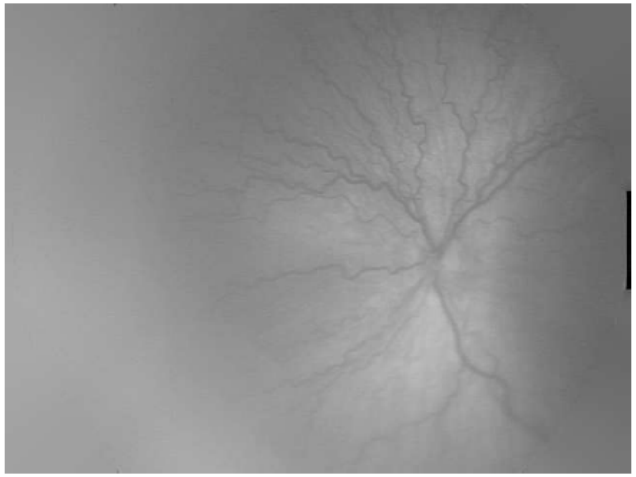
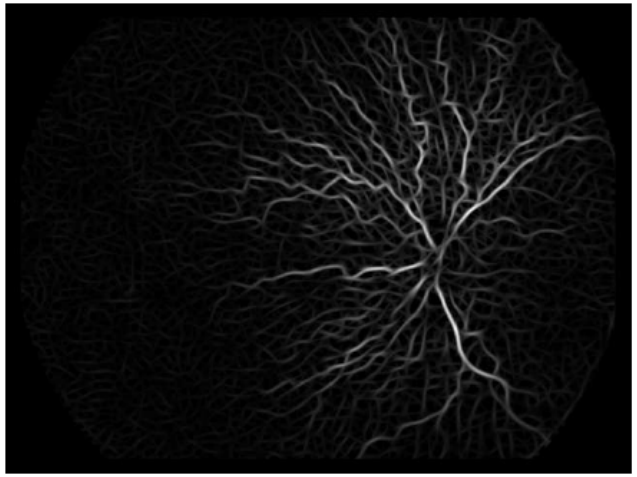
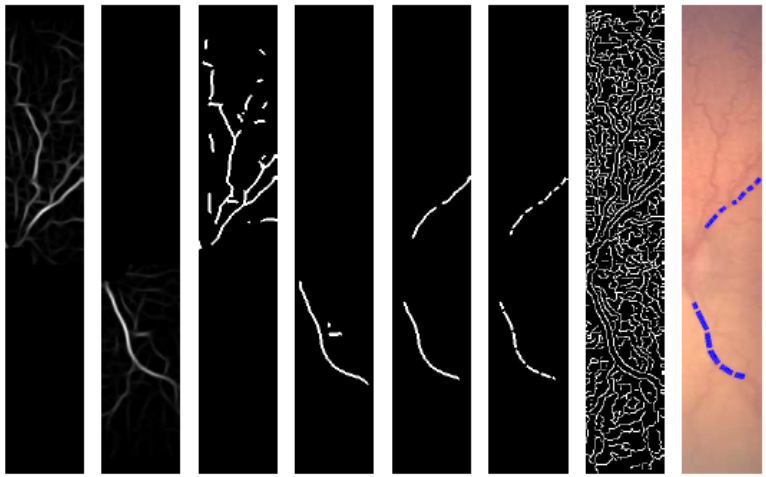
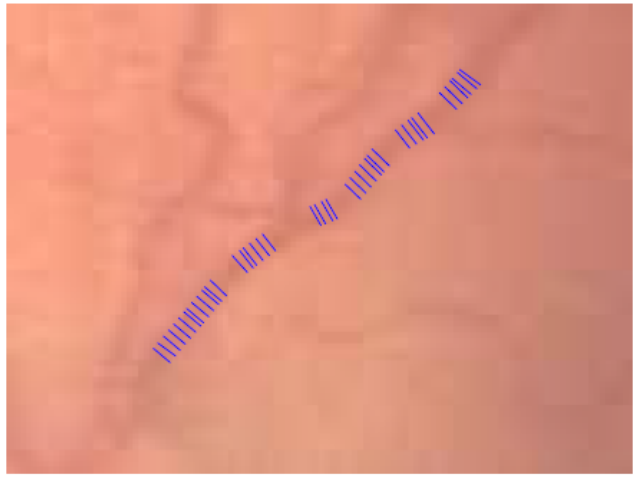
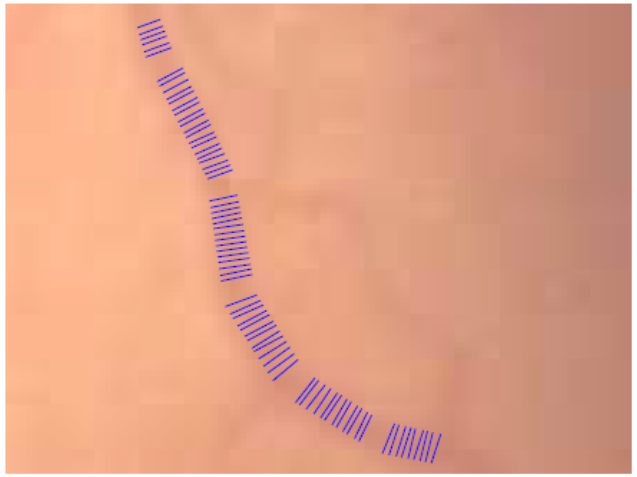
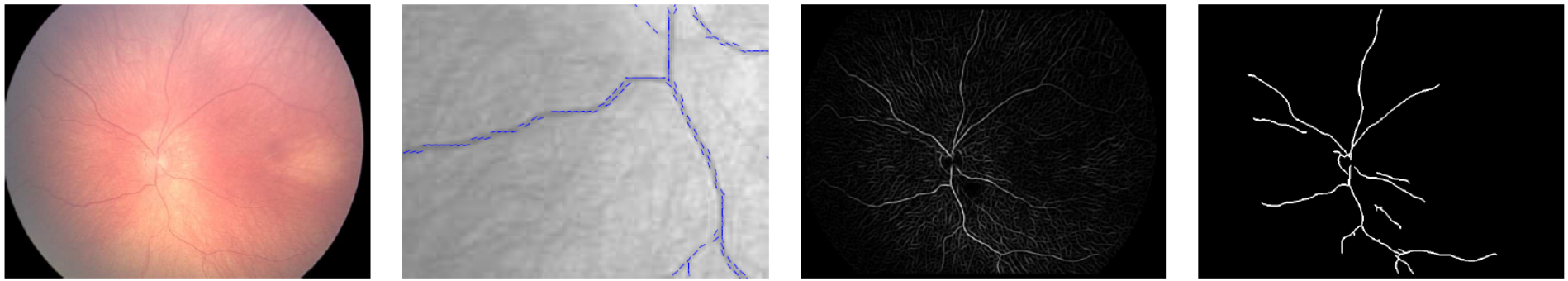
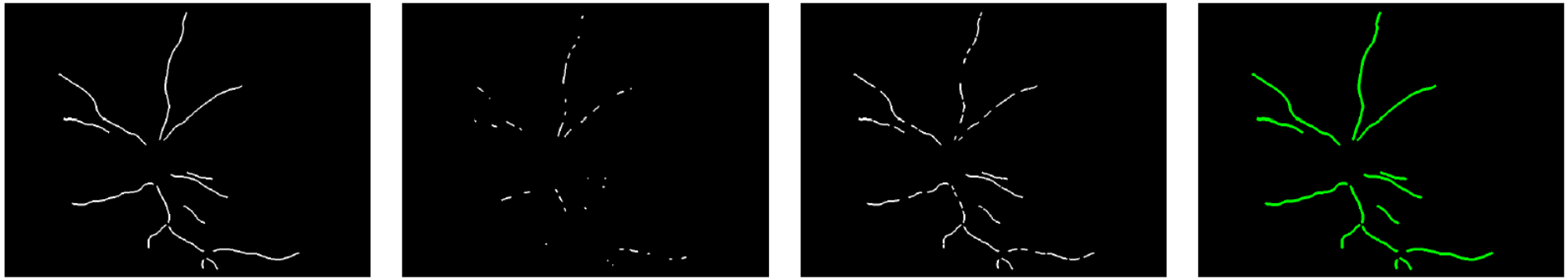
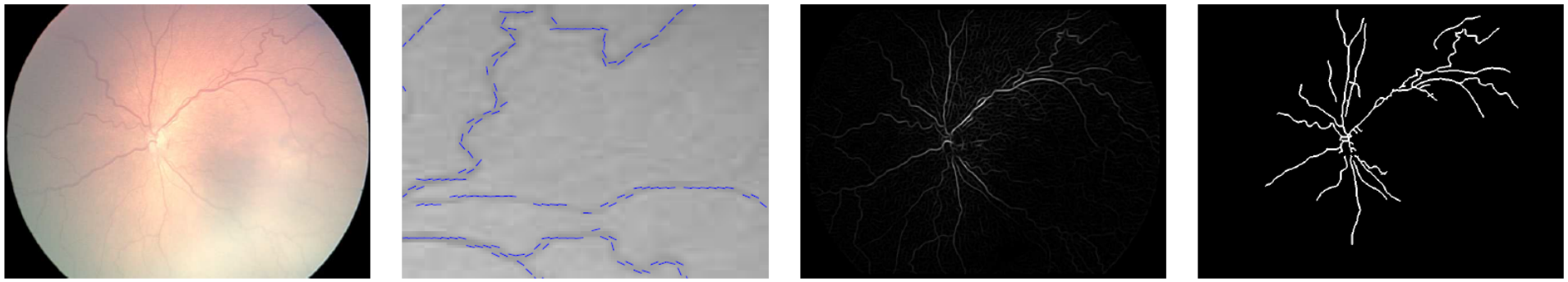
Major Temporal Arcade Width: Plus Disease 125 ± 17 µm

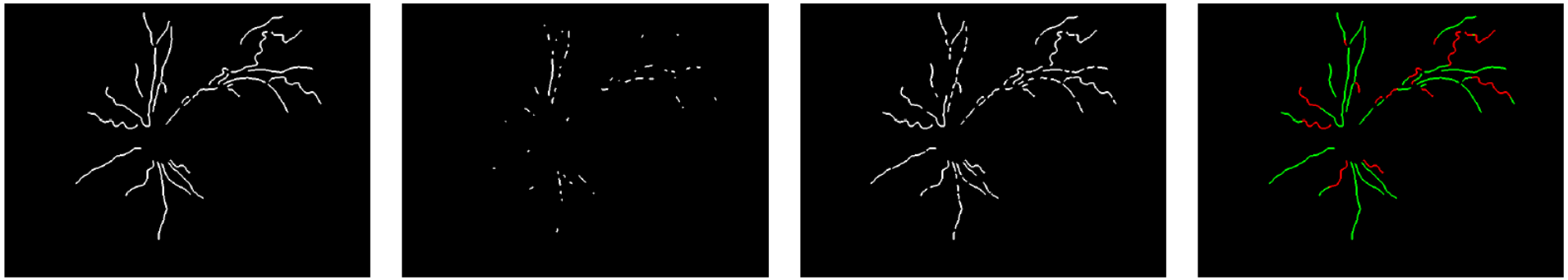


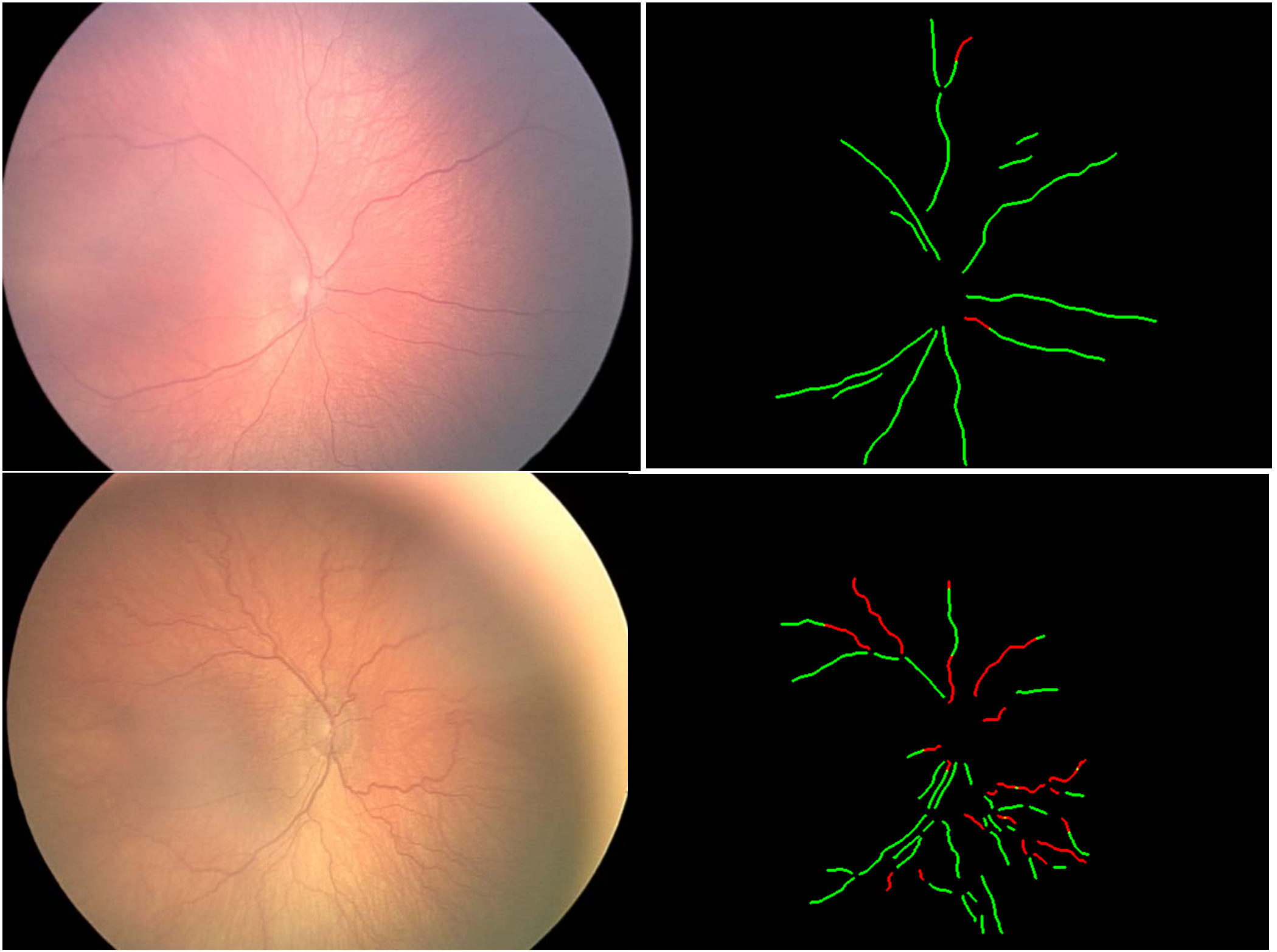
Length of tortuous vessels: no plus disease 0 mm





plus disease 11.75, 4.20, 1.99, 1.42 mm





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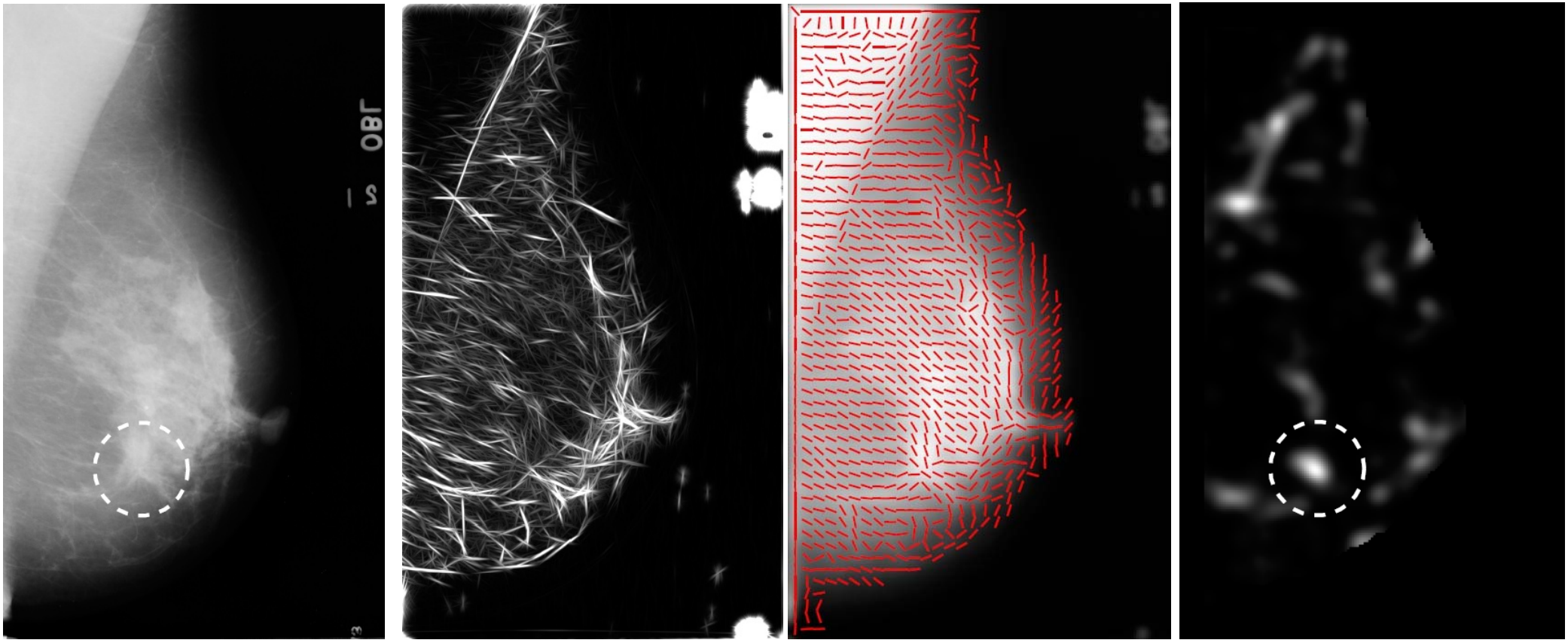
Computer-aided Diagnosis of Subtle Signs of Breast Cancer



Detection of Architectural Distortion

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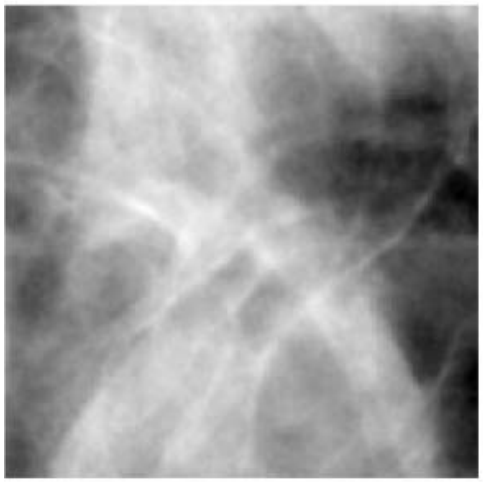
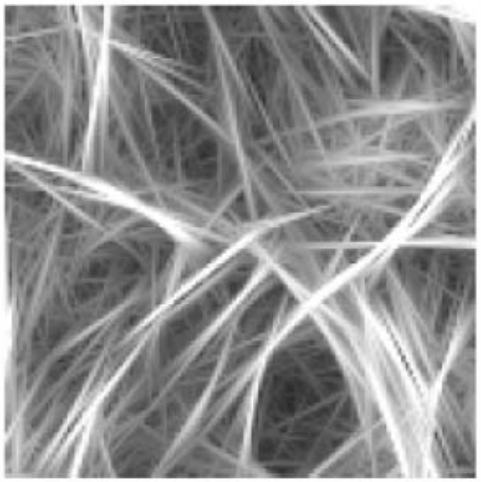
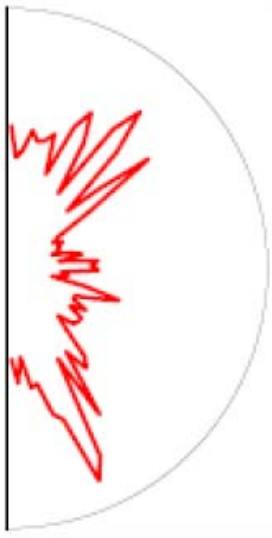
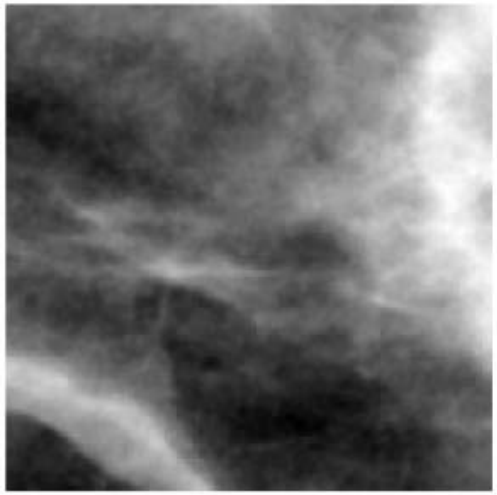
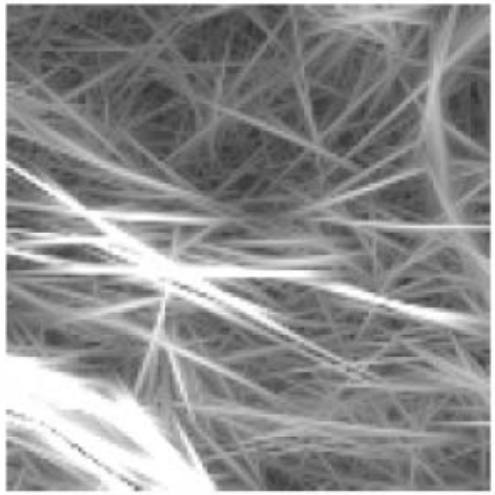
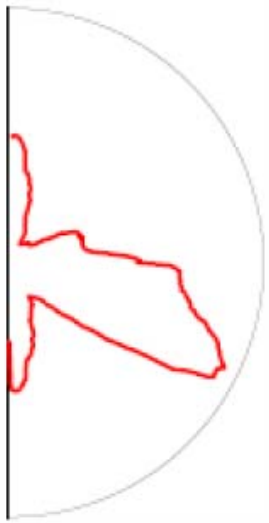
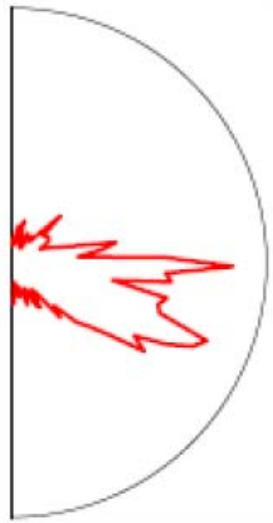
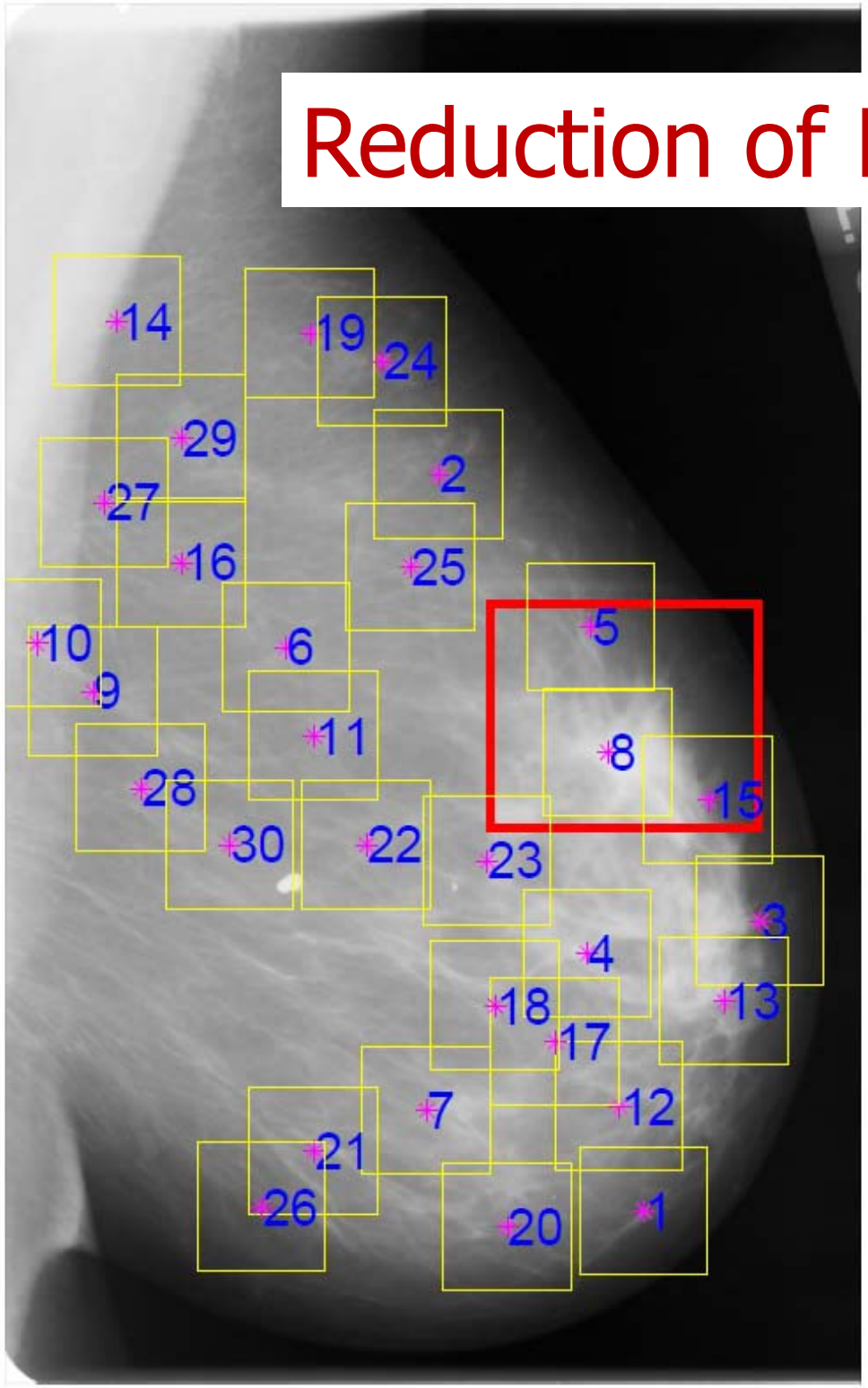
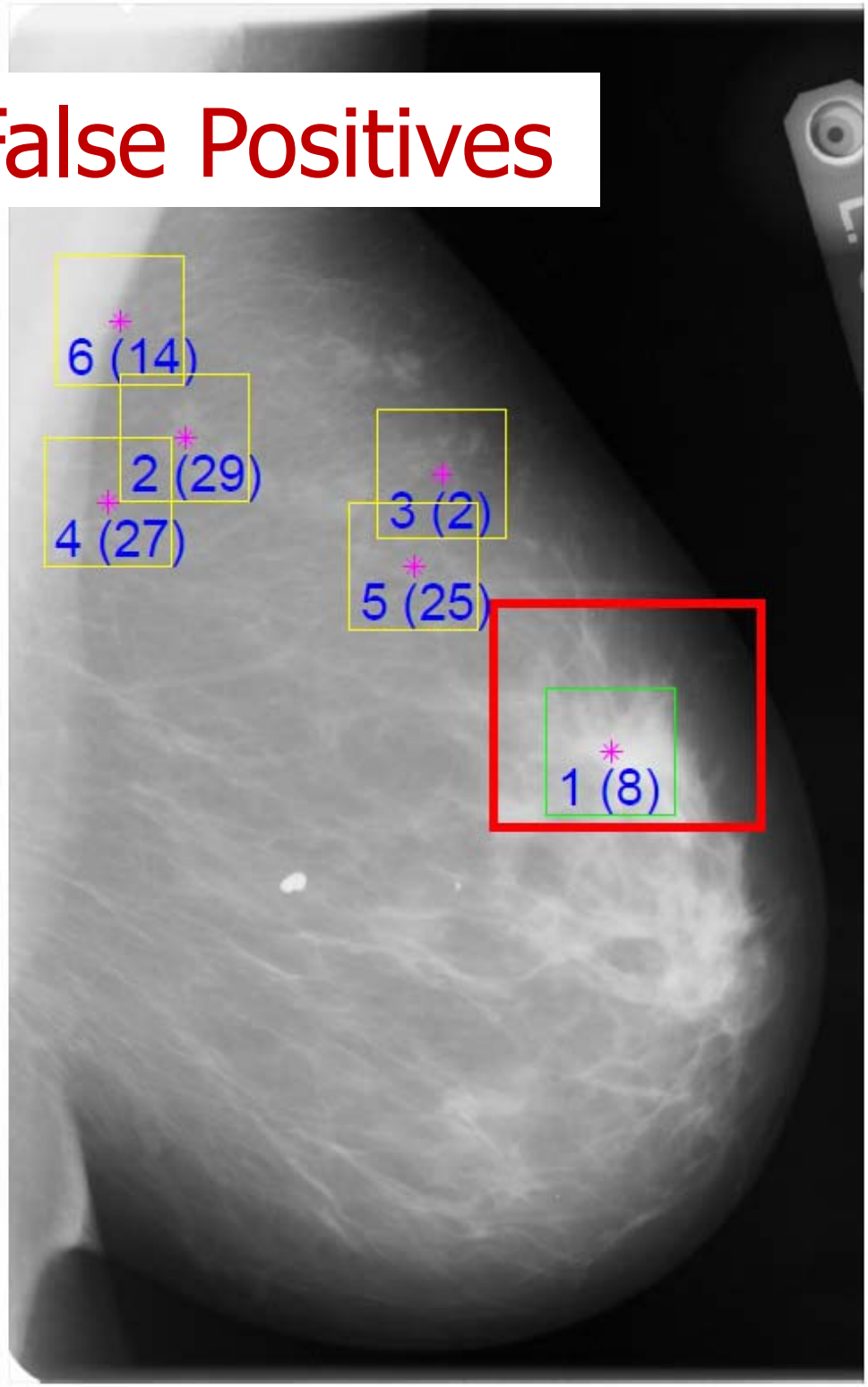
$$H_\theta = -\frac{1}{S}\sum_\theta S_{a,b}(\theta)\log_2\left(\frac{S_{a,b}(\theta)}{S}\right)$$

Reduction of False Positives





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Trends in Biomedical Engineering

- Robotic surgery
- Image-guided diagnosis and therapy
- Personalized diagnosis and prognosis
- Wearable sensors, instruments, computers
- Assistive devices and systems
- Artificial tissues and organs
- Home-based monitoring of the elderly
- Lab-on-a-chip
- Interfacing implanted chips and instruments to biological tissues and systems

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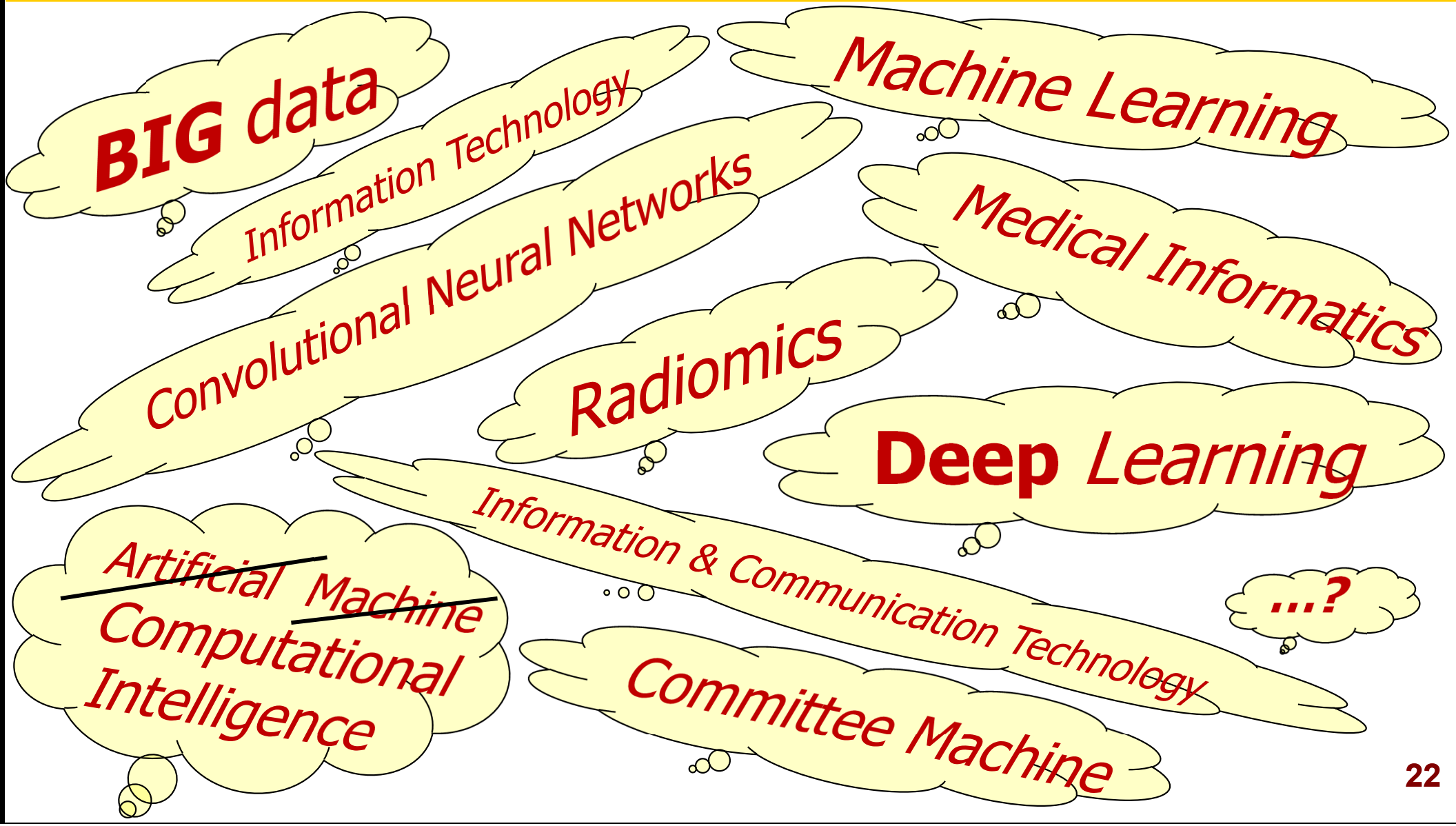
Popular Terminology and New Buzz Words…



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Desired Personal Traits of an Engineering Researcher

- Recognizing personal strengths and limitations
- Being open for collaborative team work: being a part of the whole
- Being open to asking questions and replying in simple and clear terms
- Appreciating the contributions of coworkers
- Respecting professional boundaries
- Developing good interpersonal skills
- Explaining and defending the work done

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Benefits of Multidisciplinary Research

- Advanced learning of various subjects
- Improved teaching skills
- Higher levels of knowledge and understanding
- Research publications and books
- Innovative solutions to problems in multiple and real-life application areas
- New and improved devices, tools, and systems
- Improved wellbeing, quality of life, and environment

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Perspectives on Engineering Education

- Focus on the scientific fundamentals
- Emphasize theoretical knowledge
- Never ignore or downgrade mathematics
- Learn to solve problems
- Recognize multiple applications
- Endeavor to be creative
- Strive to be original
- Develop skills to design and innovate
- Build teams to work together

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Thought-provoking Teaching

- Pay uncompromising attention to theoretical and scientific fundamentals
- Focus on the basics of physics, chemistry, and mathematics and their applications
- Provide numerical and pictorial examples to illustrate basic concepts with real-life problems
- Engage with tutorials to stimulate and assist understanding of the theoretical concepts and their practical applications

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Lively Laboratories

- Design lab exercises to apply and explore theoretical concepts in practical contexts
- Focus on hands-on experiments with real-life systems and measurements
- Aim to solve real-life problems
- Limit use of simulation packages
- Engage small groups in projects to encourage research, design, synthesis, collaboration, team work, communication, and innovation

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Research-Informed Teaching

- Advanced teaching and learning should be tightly coupled with current research
- Theoretical and application-related material in advanced courses should be related to the results of recent and relevant research
- Interesting real-life examples may be drawn from or created based on current research
- Reliance on textbooks only is not adequate
- Mirror versus lamp analogy

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Tough Tests and Exciting Exams

- Develop tough tests that challenge the students' understanding of the material
- Design exams that excite and engage the brain in deep thought processes to solve interesting real-life problems
- Avoid recycling material from question banks, textbooks, manuals, and well-known sources
- Refrain from giving trivial and easy exams

These will make you unpopular!

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Do Not Sugar-coat Engineering!

- No Funnification! Avoid the trend to promote engineering as a "fun" subject
- Engineering is not easy
- Engineering requires a solid base in science
- Engineering is not for the faint-hearted
- Engineering requires commitment
- Engineering requires dedicated study and hard work
- Let it be so!

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Levels of Knowledge

- Basic knowledge
- Fundamental knowledge
- Theoretical knowledge
- Focused knowledge
- Application-based knowledge
- Practical knowledge
- Broad-based knowledge
- Expert knowledge

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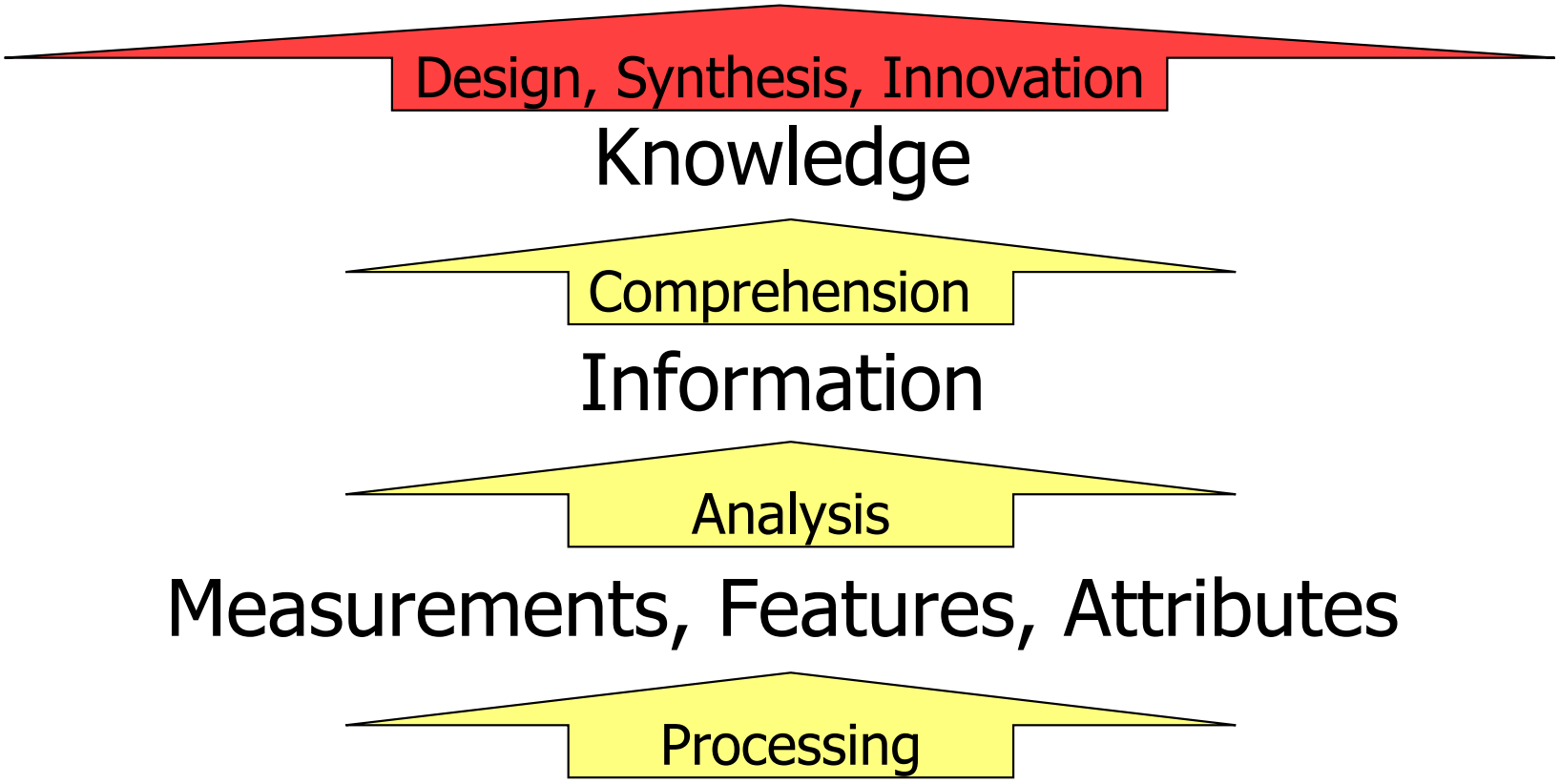
The Engineering Way
From Data to Expertise

Creativity, Intelligence, Expertise



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Perspectives on the Engineering Career

Indian engineering degrees are respected and recognized around the world!

- Maintain a broad expertise and an open mind
- Develop good social & communication skills
- Maintain professional interpersonal relationships
- Be imaginative in looking for practical applications of knowledge gained
- Collaborate with experts in multiple domains
- Gain multidisciplinary experience
- Contribute to the society and the environment!

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Social Responsibility

- Ensure that your work does not harm the global environment, flora, and fauna
- Minimize your carbon footprint
- Be sensitive to local culture and traditions
- Respect legal, social, and ethical concerns
- Never lose attention to safety and integrity
- Always keep in mind betterment of humanity and improvement of quality of life

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Be Ready for the Future and Real Jobs!

- Read and listen with comprehension
- Build a solid fundamental knowledge base
- Possess clear and in-depth theoretical knowledge
- Develop strong technical skills
- Learn practical and multidisciplinary applications
- Sharpen your critical thinking abilities
- Speak persuasively
- Communicate effectively, write with precision
- Gain experience
- Cultivate professional behavior!

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Train to Be Prepared!

- Be creative
- Be innovative
- Be progressive
- Be agile and adaptive
- Be at the forefront of knowledge
- Be conscious of and dedicated to the needs of the society and the environment
- Be a LEADER!

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Sir MV's Words

Sir Mokshagundam Visvesvaraya (1861–1962):

Indian Engineer, scholar, Bharat Ratna

His birthday, 15th September, is Engineers' Day

"Success in life depends on action, that is, on what you do, and not what you feel or think, and the price of success is hard work."

https://en.wikipedia.org/wiki/M._Visvesvaraya
http://edu-russia.com/inspirational-quotes-from-the-books-of-great-scholars/

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…but Have Some Fun Too

http://beststudentviolins.com/Einstein.html

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and Maintain Diverse Interests

https://www.couponraja.in/theroyale/apj-abdul-kalam/

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Thank You!

Natural Sciences and Engineering Research Council of Canada

Alberta Heritage Foundation for Medical Research

Canadian Breast Cancer Foundation

My students

My collaborators

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