Rapid prototyping of medical image analytics used in clinical decision support systems

Bhanu Prakash KN
Singapore Bioimaging Consortium
Bhanu@sbic.a-star.edu.sg

May 2021
Agenda

- Introduction – About SBIC, Nature of work
- Development of Research tools
  - Challenges
  - Tools used
  - Benefits
- Use cases
  - Research studies
  - Clinical trials
  - Clinical translation
- Takeaways/Conclusion
Singapore Bioimaging Consortium – IMAGING TODAY THE MEDICINE OF TOMORROW

An Integrated multidisciplinary imaging platform

Lab of Bio-optical Imaging
Lab of Metabolic Medicine
Lab of Molecular Chemistry
Lab of Isotopic Molecular Imaging
Translational Cardiovascular Imaging
Signal and Image Processing
Metabolic Imaging
MR Methods Development
Neuroscience Cluster
Fat Metabolism & Stem cell

Research
Neuroscience          Obesity & Diabetes
Cancer                Skin
Metabolism            Woman health
Stem cell             Food Quality
Cardiovascular        Optics
Need Statement: SBIC – A Bioimaging Institute

SBIC is place on earth for every Image & Data Analytics enthusiast

Multimodal Images
Optical, CT, MR; Cells, tissues; organs; structural, functional

Spectrum of research
Liver, brain, abdomen, cardiac; cancer, metabolism, neuro

Research & Clinical tools
Variability in data, limited data, user interaction; Specific to need

Image Reconstruction; Image Denoising; Artifact Reduction; Super resolution
Research Tools
Big data analytics; Inverse problems; Signal processing; Live cell analysis
Multimodal Data Analytics; Decision Support systems
Advanced Image analysis & Deep Learning

CREATING GROWTH, ENHANCING LIVES

Multimodal Images
Optical, CT, MR; Cells, tissues; organs; structural, functional

Spectrum of research
Liver, brain, abdomen, cardiac; cancer, metabolism, neuro

Research & Clinical tools
Variability in data, limited data, user interaction; Specific to need

Image Reconstruction; Image Denoising; Artifact Reduction; Super resolution
Research Tools
Big data analytics; Inverse problems; Signal processing; Live cell analysis
Multimodal Data Analytics; Decision Support systems
Advanced Image analysis & Deep Learning

CREATING GROWTH, ENHANCING LIVES

Need Statement: SBIC – A Bioimaging Institute

SBIC is place on earth for every Image & Data Analytics enthusiast

Multimodal Images
Optical, CT, MR; Cells, tissues; organs; structural, functional

Spectrum of research
Liver, brain, abdomen, cardiac; cancer, metabolism, neuro

Research & Clinical tools
Variability in data, limited data, user interaction; Specific to need

Image Reconstruction; Image Denoising; Artifact Reduction; Super resolution
Research Tools
Big data analytics; Inverse problems; Signal processing; Live cell analysis
Multimodal Data Analytics; Decision Support systems
Advanced Image analysis & Deep Learning

CREATING GROWTH, ENHANCING LIVES

Multimodal Images
Optical, CT, MR; Cells, tissues; organs; structural, functional

Spectrum of research
Liver, brain, abdomen, cardiac; cancer, metabolism, neuro

Research & Clinical tools
Variability in data, limited data, user interaction; Specific to need

Image Reconstruction; Image Denoising; Artifact Reduction; Super resolution
Research Tools
Big data analytics; Inverse problems; Signal processing; Live cell analysis
Multimodal Data Analytics; Decision Support systems
Advanced Image analysis & Deep Learning

CREATING GROWTH, ENHANCING LIVES
Why we need Imaging & Image Processing?

Medical imaging is the process of using technology to view in vivo for:

- Structural & functional understanding
- Diagnosis & monitoring, and
- treating medical problems.

Most medical imaging data is Qualitative in nature

Images
Qualitative analysis

Understanding
Quantitative information

Improved visualization;
High resolution;
in-vivo understanding;
enhanced detection; interpretation, diagnosis etc.
Quality of Acquisitions – Garbage in; Garbage out

- Limitations in Scanner settings
- Acquisition Variations
- Anatomical Variations
- Motion Artifacts
Practical issues

- Data from different hospitals
- Multiple scanners – Siemens, GE, Toshiba, Philips
- Different scan settings
- Varying slice thickness 2.5mm – 8mm
- Varying window settings
- Variability in ground truth
- Variability in Blood HU
- Artifacts and Noise
- Head tilt
Some real-life examples - Continued

Improper placement & taping, Water suppression not activated, phase swaps, Motion compensation not in place, etc.

Bias-field spoils segmentation

MPRAGE signal inhomogeneity from surface coil

Add MP2RAGE-T1 with no signal inhomogeneity

Poor segmentation

Improved segmentation

Acknowledgment: Isaac Huen, PhD, SBIC

Image based pain points

- ML or DL needs painful, time-consuming, & expensive data annotation
- Multiple blinded annotations of different types
- Domain expertise

Radiologists Already Overloaded

- Data sets could be – long videos (Colonoscopy) – Marking of polyps
- Very small structures – Knee cartilage; Gastric cancer wall thickening
- 4D & Longitudinal data sets – Cardiac, Treatment phase, Clinical trials
- Limited data sets – Rare conditions

Time, Errors, Variability, Cost

- Access to data
- Right tools for Annotation & exporting
- Combining Multimodal unstructured data; Text & Images
- Missing information; Causality etc.

Scalability, Tool development
Stroke Suite Roadmap

Stroke is the No. 1 cause of adult disability
High mortality, morbidity, social & economical burden
Time critical to treat
2 million brain cells die per minute

Stroke onset timeline:
- Stroke incidence prediction: > 5 years
- Detection: 6 hours
- Treatment: 10 days
- Treatment/no treatment outcome prediction: 1 year
Landmark calculation based on ellipse fitting


Volkau I, Bhanu Prakash KN, Ng TT, Gupta V, Nowinski WL: Localization of brain landmarks such as the anterior and posterior commissures based on geometrical fitting. US patent no. US8,045,775 granted on 25 Oct 2011.

Curve Fitting
Fuzzy Logic
GUI Layout
Global Optimization
Image Processing
MATLAB Compiler
Optimization
Partial Differential Equation
Signal Processing
Statistical Parametric
Statistics & Machine Learning
Symbolic Math Toolbox
Registration of atlas, sparse data & time series based on ellipse fitting – Low computation / fast

**Hemorrhage: days 3 and 4**

![Hemorrhage Images]

**Ischemic stroke: days 1 and 6**

![Ischemic Stroke Images]

**Atlas-scan registration**

![Atlas-scan Registration Image]

- Helps Quantification
- Understanding changes
- Supports decision making
- Robust, Accurate & efficient
- Eliminates user bias
- Manhours saved


Volkau I, Bhanu Prakash KN, Ng TT, Gupta V, Nowinski WL: Localization of brain landmarks such as the anterior and posterior commissures based on geometrical fitting. US patent no. US8,045,775 granted on 25 Oct 2011.
Stroke detection / localization on NCCT


Improved detection, Time efficient, Accurate
Hemorrhage stroke quantification & tracking


Fat Analysis tools in Rodents and Humans

- Adiposity levels associated with risk of metabolic diseases.
- Physiologic effects based on anatomical location.
- Abdomen:
  - **Visceral Adipose Tissue (VAT)**
  - **Subcutaneous Adipose Tissue (SAT)**
    - Superficial SAT
    - Deep SAT
    - Separated by Fascia Superficialis

![Abdominal image](image_url)

**Level sets & Graph cut methods**

**Human Abdominal fat compartments**

Automated segmentation of visceral and subcutaneous (deep and superficial) adipose tissues in normal and overweight men

Suresh Anand Sadananthan PhD, Bhanu Prakash KN, PhD ... See all authors

First published: 07 May 2014 | [https://doi.org/10.1002/jmri.24655](https://doi.org/10.1002/jmri.24655) | Citations: 36
Framework developed in MATLAB – saved manhours ~ 1000 hours

Data selection

Data View

Man hours saved > 1000 hrs
MATLAB based Rodent Fat Analysis tool

Original image → Initial contour → VAT → Final Segmentation

Lipids
Fat Storage-inducing Transmembrane Protein 2 Is Required for Fat Storage in Adipose Tissue

Cell Metabolism
Adipocyte Ceramides Regulate Subcutaneous Adipose Browning, Inflammation, and Metabolism

Effect of Exercise and Calorie Restriction on Tissue Acylcarnitines, Tissue Desaturase Indices, and Fat Accumulation in Diet-Induced Obese Rats

PLOS ONE
Quantification of Abdominal Fat Depots in Rats and Mice during Obesity and Weight Loss Interventions

Narcilasine attenuates diet-induced obesity by promoting oxidative metabolism in skeletal muscle
MATLAB based Rodent abdominal fat segmentation tool

Data View

Data selection

Processing

Parameter selection

Segmentation

Results

Man hours saved > 1000 hrs
Take Home message / Conclusions

Finalizing image processing before starting study has advantages:
- Image quality fit for purpose
- Measured variables, outputs, image processing pipelines are finalized
- Hypotheses can be framed and pre-registered

Disadvantage
- May require manpower and expertise for optimization

Recommendations
- Have a pilot study
- Test / optimize the acquisition together with image processing

... saved manhours, saved cost, improved accuracy, easy to prototype, easy to learn, deployable, ...
Acknowledgements

Singapore Bioimaging Consortium (SBIC)
Agency for Science, Technology & Research (A*STAR)
Prof. Wieslaw L Nowinski -- Biomedical Imaging Lab, SBIC
Dr. Sendhil Velan – Principal Investigator – SBIC
Dr. Varsha Gupta – SICS
Dr. Ihar Volkov – NTU
Dr. Kuan Jin Lee – SBIC
Johns’ Hopkins Hospital – USA
National University Health Systems, Singapore
THANK YOU

www.a-star.edu.sg