Towards Better than Human Capability in Diagnosing Prostate Cancer Using Infrared Spectroscopic Imaging

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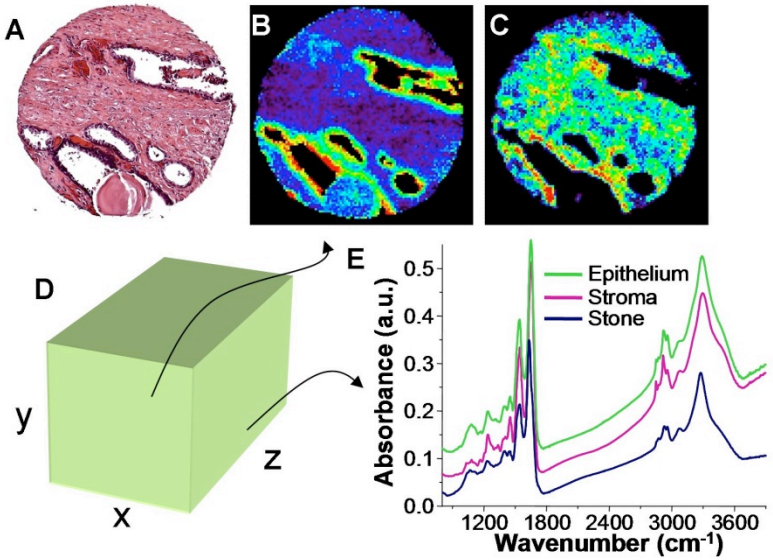
Prostate Cancer Diagnosis using FTIR

- Pathologist diagnose cancer from structures in stained tissue.
- Fourier transform infrared spectroscopy imaging.
  - Combines chemistry and structure
- The sweep of the tissue provides a 3D spectral image.



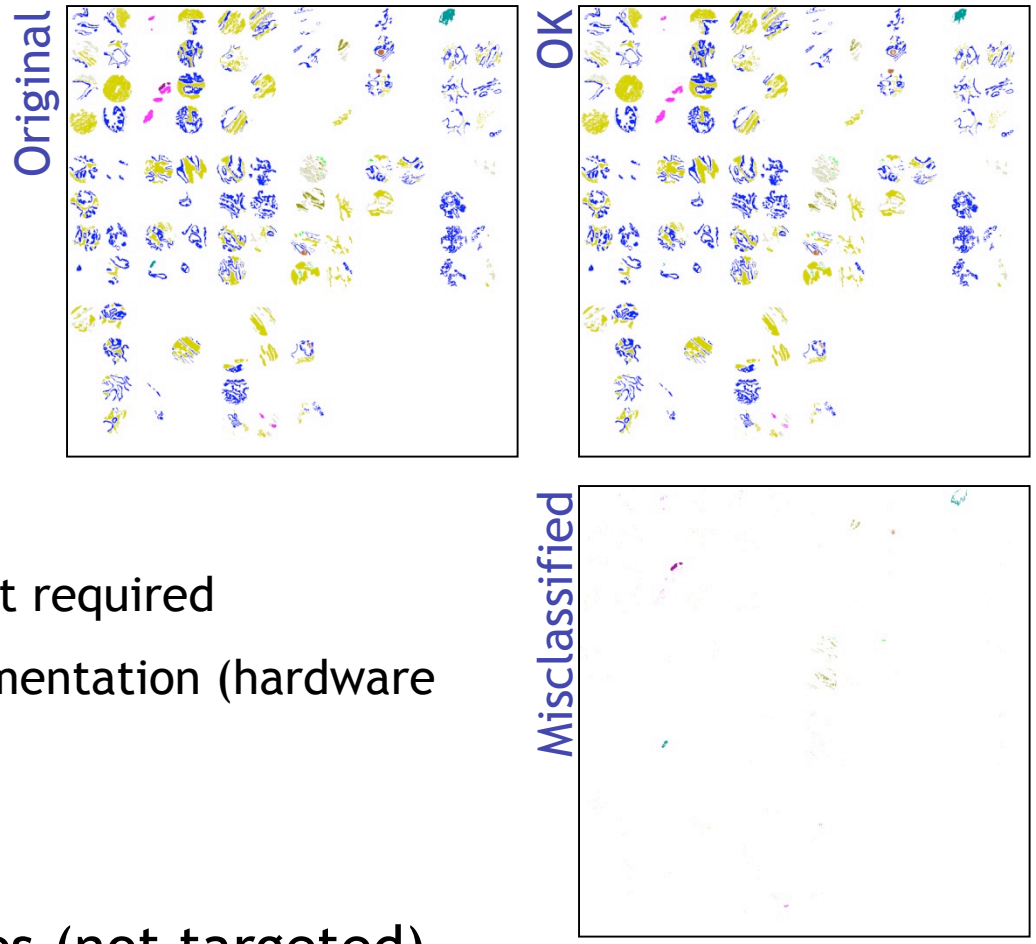
- The spectra contain a chemical signature of the cell/pixel.
- Two step process:
  - Tissue identification (key tissue: epithelial/stroma)
  - Diagnose anomalous tissues (benign/malignant/degree)

Why Does This Matter?

- One in six men will be diagnosed with prostate cancer (US) during their lifetime.
- Pathologist opinion of structures in stained tissue is **the** definitive diagnosis for almost all cancers
  - Also critical for therapy, drug development, epidemiology, public policy.
- Biopsy-staining-microscopy-manual recognition approach has been used for over 150 years.
- No automated method has far proven to be human competitive.
- The lack of automation leads to
  - heavy workloads for pathologists, increased costs and errors.
- The method can be generalized to biopsies of any type of cancer (current studies include prostate, colon, and breast)

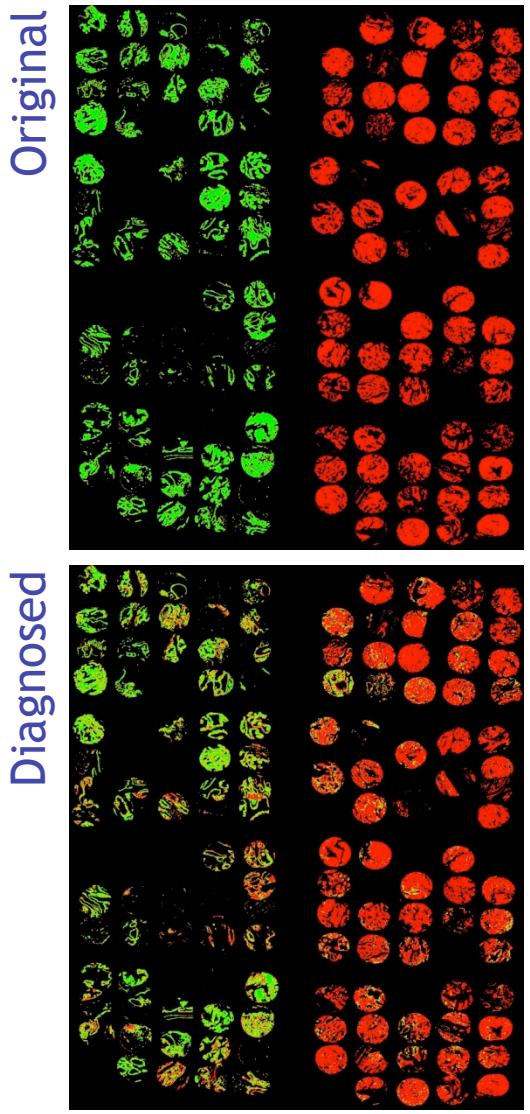
GBML Identifies Tissue Types Accurately

- Large volume of labeled arrays
- Spectra transformed (features, tissue type)
- Incremental rule learning based on set covering:
  - Reduce the memory footprint required
  - Efficient and scalable implementation (hardware and software parallelization)
- Accuracy >96%
- Mistakes on minority classes (not targeted) and boundaries



Filtered Tissue is Accurately Diagnosed

- Epithelial and stroma used for diagnosis
- Spectra transformed (features, diagnosis)
- GBML to reproduce human diagnosis
- Pixel crossvalidation accuracy (87.34%)
- Spot accuracy
  - **68 of 69** malignant spots
  - **70 of 71** benign spots
- Human-competitive computer-aided diagnosis system is possible
- First published results that fall in the range of human error (<5%)



Human Competitive Claims: Criteria B,D,E

- Criterion B: The result is equal to or better than a result that was accepted as a new scientific result at the time when it was published in a peer-reviewed scientific journal.
- Criterion D: The result is publishable in its own right as a new scientific result 3/4 independent of the fact that the result was mechanically created.
- Criterion E: The result is equal to or better than the most recent human-created solution to a long-standing problem for which there has been a succession of increasingly better human-created solutions.

Criterion B: Better Than Result Accepted As A New Scientific Result

- Current best published result, examples from different fields
  - Image Analysis - 77% accuracy[1] (cancer/no cancer)
  - Raman Spectroscopy – 86%[2] accuracy
  - Genomic analysis – 76% (low grade/high grade cancer)
- FTIR
  - 2 out of 140 samples detected wrong (this study)
- GBML results
  - First automated method to replicate human accuracy in diagnosis
  - General approach applicable to different types of tissue/cancer
  - Advances on GBML mine large scale data sets

1. R. Stotzka *et al. Anal. Quant. Cytol. Histol.,17, 204-218 (1995).*
2. P. Crow *et al. Urol.* 65, 1126-1130 (2005)
3. L. True *et al.* Proc Natl Acad Sci U S A. 2006 Jul 18;103(29):10991-10996.

Criterion D: GBML Results are Publishable

- Paper in GECCO in the Real World Applications track
- Journal article in press:
  - Jounal of Natural Computing. Special issue on Learning Classifier Systems (Ed. Larry Bull)
- Preparing a unifying book chapter describing the complete process:
  - Learning Classifier Systems in Data Mining (Ed. Larry Bull and Ester Bernadó)
- Preparing a journal article for a top medical journal on the results and implication for clinical diagnosis:
  - Nature Medicine

Criterion E: The result is equal to or better than the most recent human-created solution

- Previous models were unable to match pathologist accuracy
- Patient diagnostic accuracy did not break the 75-90% barrier
- Our approach:
  - Accurately predict 87.43% of the raw pixels
  - Overall patient diagnosis accuracy >95%, which is in the region of human performance by the *world's leading authorities* in prostate cancer
  - Likely beats community and average pathologists
    - Lack of studies due to liability issues and follow up problems

Why This is the "Best" Among Other HUMIES Submissions?

- **Social impact:** Prostate cancer accounts for one-third of noncutaneous cancers diagnosed in US men and it is a leading cause of cancer-related death.
- **Interdisciplinary effort:** Combine expertise in molecular chemistry, microscopy image processing for spectroscopy and structural information, optimization, and genetics-based machine learning.
- **Methodology transference:** Our current initial experiments with other tissues—breast and colon—show very similar human-competitive results.
- **Breakthrough:** First human-competitive results in 150 years.