

PAAT:

A digital Pathology platform for Automated Diagnosis and Classification of Cervical Cancer from pap-smear Images



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Background

Cervical Cancer Prevalence

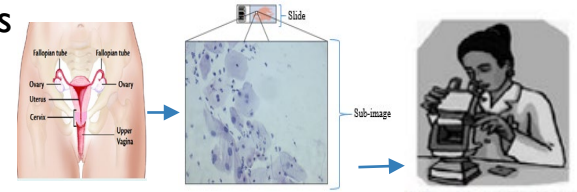


- ❑ Globally, cervical cancer ranks 4th most prevalent cancer.
- ❑ 570,000 new cases reported in 2018 (WHO, 2018)
 - ❑ representing 6.6% of all female cancers
- ❑ Highest incidences are in Africa.
 - ❑ 34.8 new cases diagnosed per 10,000 (WHO, 2017)
- ❑ Over 80% is detected in its late stages.
- ❑ Approximately 90% occur in less developed countries.
- ❑ **Uganda**
 - ❑ ranked 14th and 7th Globally and in Africa respectively
 - ❑ Over 80% of those diagnosed die.

Where is the Problem

Pap-smears....

- ❑ Pap-smear screening
 - ❑ Regular and commonest screening method
 - ❑ Most successful attempt for early detection of cervical cancer
- ❑ However the manual analysis
 - ❑ Time consuming, laborious and error prone
 - ❑ Human visual grading for images is subjective, and inconsistent
 - ❑ Inter-and intra-observer variations
 - ❑ Monotonous
- ❑ Digital Microscopes
 - ❑ Expensive
 - ❑ Limited impact in LMIC
- ❑ Commonest low cost microscopes
 - ❑ Manual hence require experienced users
 - ❑ Limited capability of storing images for latter analysis
- ❑ Risk factors analysis NOT sufficiently incorporated into screening

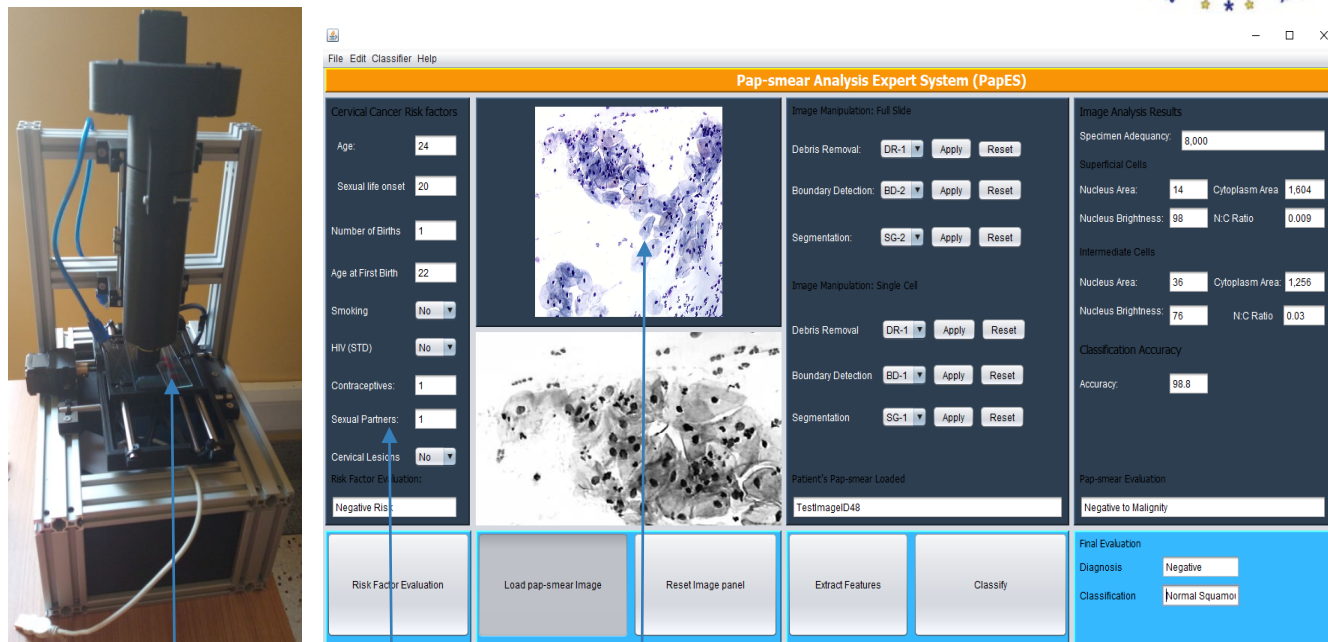


Hence need for digital pathology platform for automated diagnosis and classification of cervical cancer from pap-smear images

A digital pathology platform

The digital pathology platform is in 3 fold:

Our Solution



(i) a low-cost digital microscope sliding scanner, (ii) cervical cancer risk factors evaluation engine, and (iii) a pap-smear analysis tool.

Approach

Methodology....



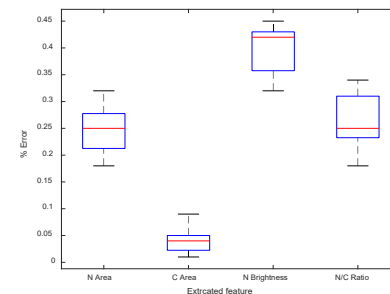
- ❑ Low cost microscope slide scanner
 - ❑ **Quick, reliable and high resolution pap-smear image**
 - ❑ Most of the parts have been 3D printed
 - ❑ Cheap available Electronics
 - ❑ Custom software written in C++
- ❑ Cervical cancer risk factors assessment
 - ❑ **Possibility of contracting cervical cancer given risk factors analysis**
 - ❑ Implemented using fuzzy logic
 - ❑ Based on knowledge base and rules of inference by expert cytopathologists
- ❑ Pap-smear analysis
 - ❑ **Automated analysis of pap-smears for cervical cancer diagnosis & classification**
 - ❑ Scene segmentation: TWIS
 - ❑ Debris removal: 3-phase sequential elimination method
 - ❑ Feature selection: Simulated annealing with a wrapper filter
 - ❑ Classification: An enhanced fuzzy c-means algorithm
- ❑ Evaluation
 - ❑ Fryback and Thornbury's medical system evaluation criteria
 - ❑ Technical, Diagnostic accuracy and Diagnostic thinking efficacies.

Technical Efficacy: Feature Extraction.....

Results

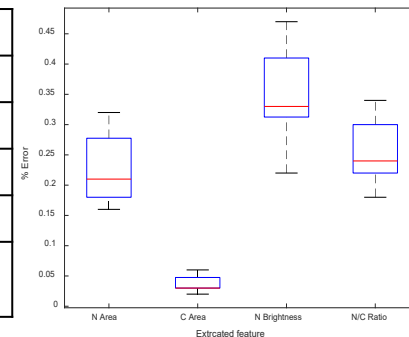
Comparison of the extracted features from a normal superficial cell by a cytopathologist and PAAT

Superficial Normal Cell	Evaluation	
Feature	Cytopathologist	PAAT
Nucleus Area	1328 μm^2	1331.67 μm^2
Cytoplasm Area	44991 μm^2	45001.85 μm^2
Nucleus Brightness	67 (Light)	67.32
Nucleus: Cytoplasm Ratio	0.02951 (Small)	0.02959



Comparison of the extracted features from an abnormal superficial cell by a cytopathologist and PAAT

Superficial Normal Cell	Evaluation	
Features	Cytopathologist	PAAT
Nucleus Area	3996 μm^2	4009 μm^2
Cytoplasm Area	7188 μm^2	7216.8 μm^2
Nucleus Brightness	97 (very dark)	97.04
Nucleus: Cytoplasm Ratio	0.555 (very large)	0.557



Technical Efficacy: Feature Extraction.....

Results

Some of individual cell segmentations using PAAT

Cancer cell type	Cancer cell class	Original	Nucleus	Cytoplasm
Abnormal Cells	Carcinoma in situ			
	Mild squamous			
	Moderate squamous			
	Severe squamous			
Normal Cells	Intermediate squamous			
	Superficial squamous			
	Columnar epithelial			

Diagnostic accuracy efficacy: Classification..

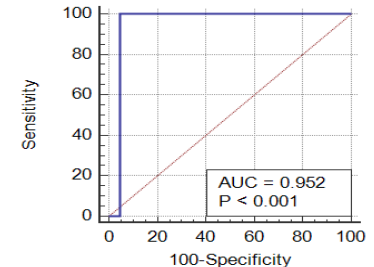
Results

- ❑ Tested on 3 datasets
 - ❑ 917 single cells (200 for training, 717 for testing)
 - ❑ 497 full slide pap-smear images (200 training, 297 testing)
 - ❑ 60 slides from pathology unit at MRRH

Metric	917 single cells	497 pap-smear slides	Pathology slides
Accuracy	98.88%	97.64%	95.00%
Sensitivity	99.28%	98.08%	100%
Specificity	97.47%	97.16%	90.0%
FNR	0.72%	1.92%	0.00%
FPR	2.53%	2.84%	10.00%
Error	1.12%	2.36%	5.00%

Confusion Matrix and ROC for 60 pap-smear cells from a pathology lab

Abnormal Slides		Normal slides	
False Negative	0	True Negative	27
True Positive	30	False Positive	3
Total	30	Total	30



Diagnostic thinking efficacy: risk factors..

Tested on 8 cases

Results

Cervical Cancer Risk factors

Age:

Sexual life onset

Number of Births

Age at First Birth

Smoking

HIV (STD)

Contraceptives:

Sexual Partners:

Cervical Lesions

Risk Factor Evaluation:
Positive to Malignity

Risk Factor Evaluation

Comparison of Risk assessment Results by the Cytopathologist and PAAT

Case	Cytology diagnosis	PAAT diagnosis	Correlation
1	Negative	Negative	Positive
2	Positive	Positive	Positive
3	Negative	Negative	Positive
4	Negative	Negative	Positive
5	Positive	Positive	Positive
6	Positive	Positive	Positive
7	Positive	Positive	Positive
8	Positive	Positive	Positive

100% correlation between the Expert System and Expert Judgement **

** - More tests being undertaken



Discussion....

Discussion

- ❑ Low cost microscope slide scanner
 - ❑ High quick, reliable and high resolution pap-smear images
 - ❑ Full pap-smear scan in less than 6 minutes **
 - ❑ Image quality comparable to images obtained with commercial microscopes
 - ❑ Low cost of approximately 150 USD compared to over 1,800 USD commercial microscopes

- ❑ Cervical cancer risk factors assessment
 - ❑ Results comparable with expert judgment **

- ❑ Pap-smear analysis
 - ❑ Features extracted by PAAT are comparable to those extracted by cytopathologist **
 - ❑ Features extracted by PAAT are comparable to those extracted by commercial tools **
 - ❑ Cervical cancer classification of single cell/full pap-smear comparable to the manual classification **

** - More tests being undertaken

Future Plans

Recommendations....

- Low cost microscope slide scanner
 - Scan more than one pap-smear at a time
 - Real time pap-smear analysis during pap-smear scanning
 - Include fluorescence for use even for other microscopy tests

- Cervical cancer risk factors assessment
 - Increase the knowledge base

- Pap-smear analysis
 - Use ANN

- Integrate an AI empowered Cervical cancer patient's Information Expert System with PAAT**
 - Allow telemedicine
 - Allow cervical cancer recurrence prediction
 - Communicate with National Cancer Registries
 - More training datasets for ANN



Key Points

Key Take Away Points to Policy Makers....



- ❑ Digital Health
 - ❑ Need to implement the eGovernment policy especially in Health
- ❑ Avail public medical datasets/repositories
 - ❑ With AI and the academic institutions in Uganda, a lot of data driven innovations/research are stagnant because of lack of data
 - ❑ Medical Data Access Bill (Confidentiality and Privacy Issues Handled)
 - ❑ Hospitals attached to Universities are key research centers to the universities
 - ❑ More cancer registries
- ❑ Increase Funds to Hospitals
 - ❑ ICT and Biomedical Engineering Units need to be prioritized in Hospitals
 - ❑ New innovations may not run on old existing computers
- ❑ Digitize cervical cancer screening workflow
 - ❑ Telemedicine support
 - ❑ Tumor board meetings management
 - ❑ Picture Archive Communication
 - ❑ Support to Personalized Health

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FACULTY OF APPLIED SCIENCES
AND TECHNOLOGY (MUST MAIN
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Thank you very much
for your time

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Thank you for Your Time