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Liveness Detection Using An Intensity Based Approach in Fingerprint Scanners

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Outline

- Background for liveness detection
- Intensity-based approach
- Results of three different scanners
- Conclusion and future work

Background

- **Fingerprint scanners are susceptible to spoof attack by “fake” fingerprints**
  - Lifted latent fingerprints
  - Artificial fingers: gummy fingers, casts made from gelatin, play-doh etc
  - Worst case: dismembered fingers
- **Liveness detection**
  - An anti-spoofing method
  - Improves reliability and security of biometric system
- **Detection of perspiration pattern**
  - Time series images
  - Developed by our lab
- **Previous algorithms**
  - Ridge signal algorithm
  - Wavelet based algorithm
- **Motivation:** improve accuracy and speed

Human Visual Difference for Live and Non-Live Fingerprint Images

0 second

5^{th} second

Live Image

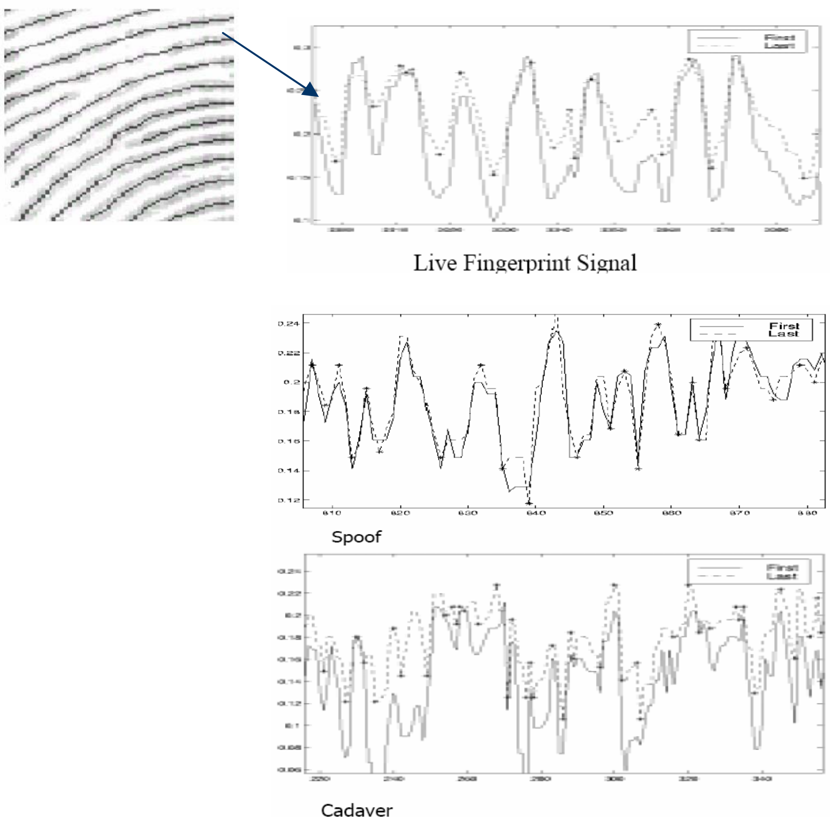
Spoof Image

Cadaver Image

Features Extraction Based on Perspiration Pattern

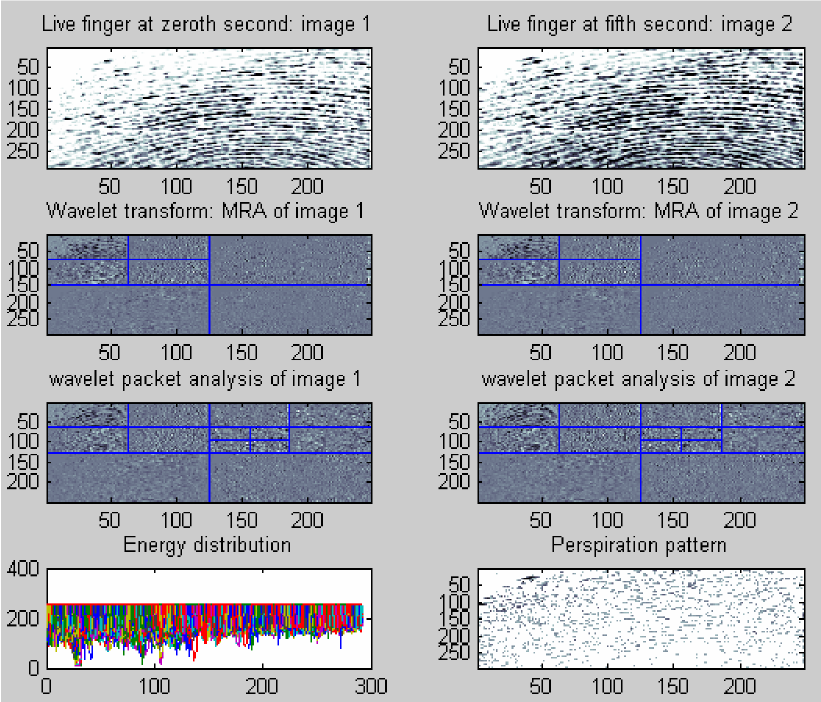
- The basis of *static* features: live fingerprints looks “patchy” due to the perspiration pattern
- The basis of *dynamic* features: live fingers demonstrate a distinctive changing moisture pattern between 0 second and 5th second images

Ridge Signal Algorithm



- Capture time-series images over 5 seconds
- Map a 2-D fingerprint image to a 1-D signal representing the grey levels along the ridges
- 7 static and dynamic features are extracted
- Perform classification between live and non-live using BPNN

Wavelet Based Algorithm



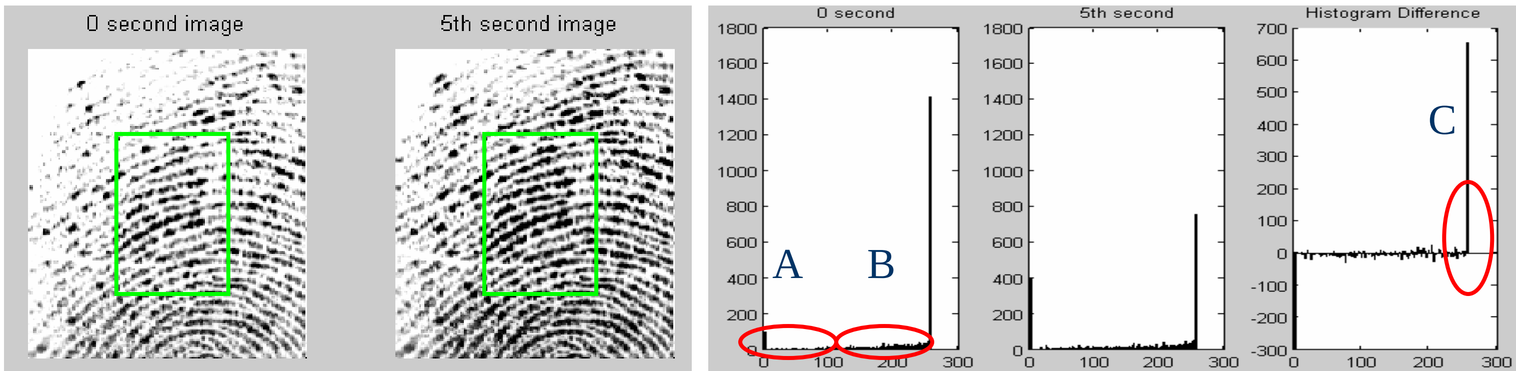
- Perform wavelet transform on 0 and 5th second images
- Extract low frequency content using multiresolution analysis
- Extract high frequency content using wavelet packet analysis
- Perform classification using energy content of changing coefficients

Intensity Based Approach

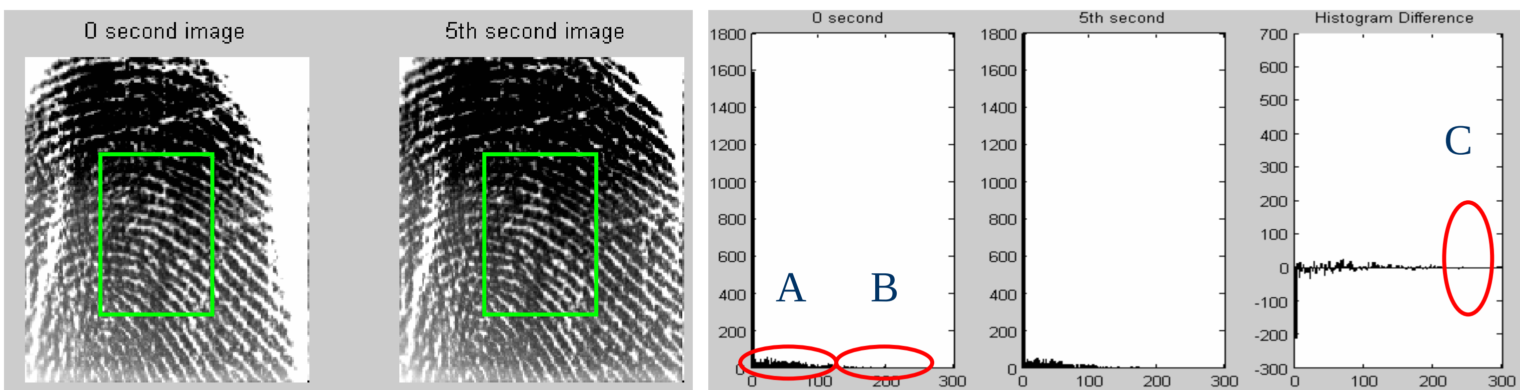
- Motivation: improve speed with reasonable accuracy
- Approach: quantify grey level differences between live and non-live fingerprint images using histogram distribution statistics
- Advantages: simple, efficient and saving time

Intensity Based Approach -Examples

Live



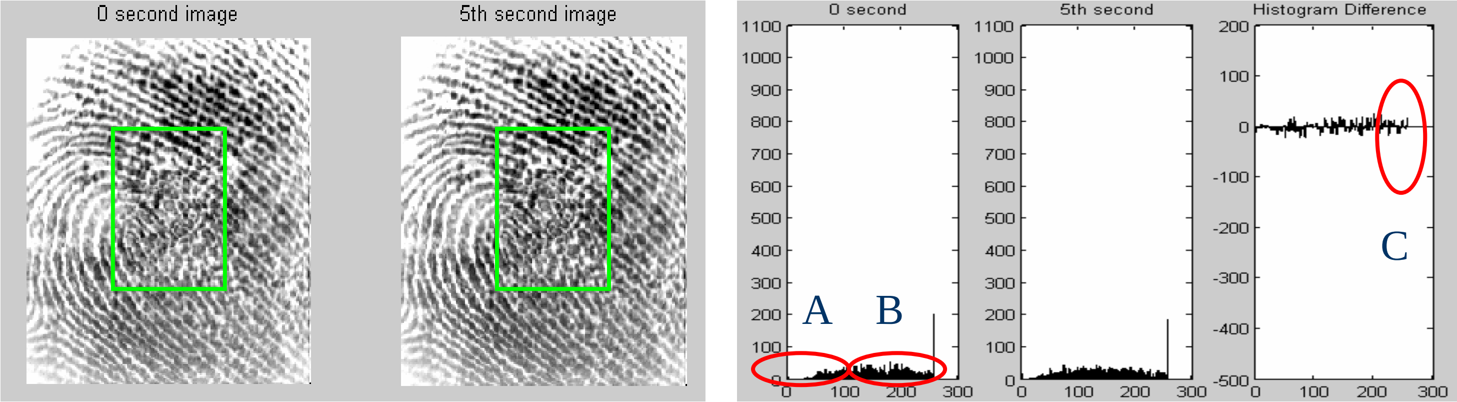
Play-Doh



Intensity based Approach -Examples (Cont.)

Gelatin

Cadaver



Intensity Based Approach -Steps

- Pre-process to remove noise and normalize
- Adaptively select interesting area
- Perform histogram distribution analysis for time-series images
- Extract static and dynamic features
- Generate and determine classification tree using training and validation dataset
- Test with final test dataset

Classification Tree

- Derives a sequence of if-then-else rules in order to assign a class label to the input data
- A data mining technique
- Commercial tools: CART, See 5, SPSS etc
- Free tool : Classification Tree in Excel

http://www.geocities.com/adotsaha/CTree/CtreeinExcel.html

Some Hints

- Different scanners have different histogram distributions
- Select appropriate features to different scanners
- Adaptively select area to avoid scars
- Some live fingerprints are very wet and change very little
- Some cadaver fingerprints change like a live finger, but their grey levels are different than live fingers
- Classification tree takes these situations into consideration

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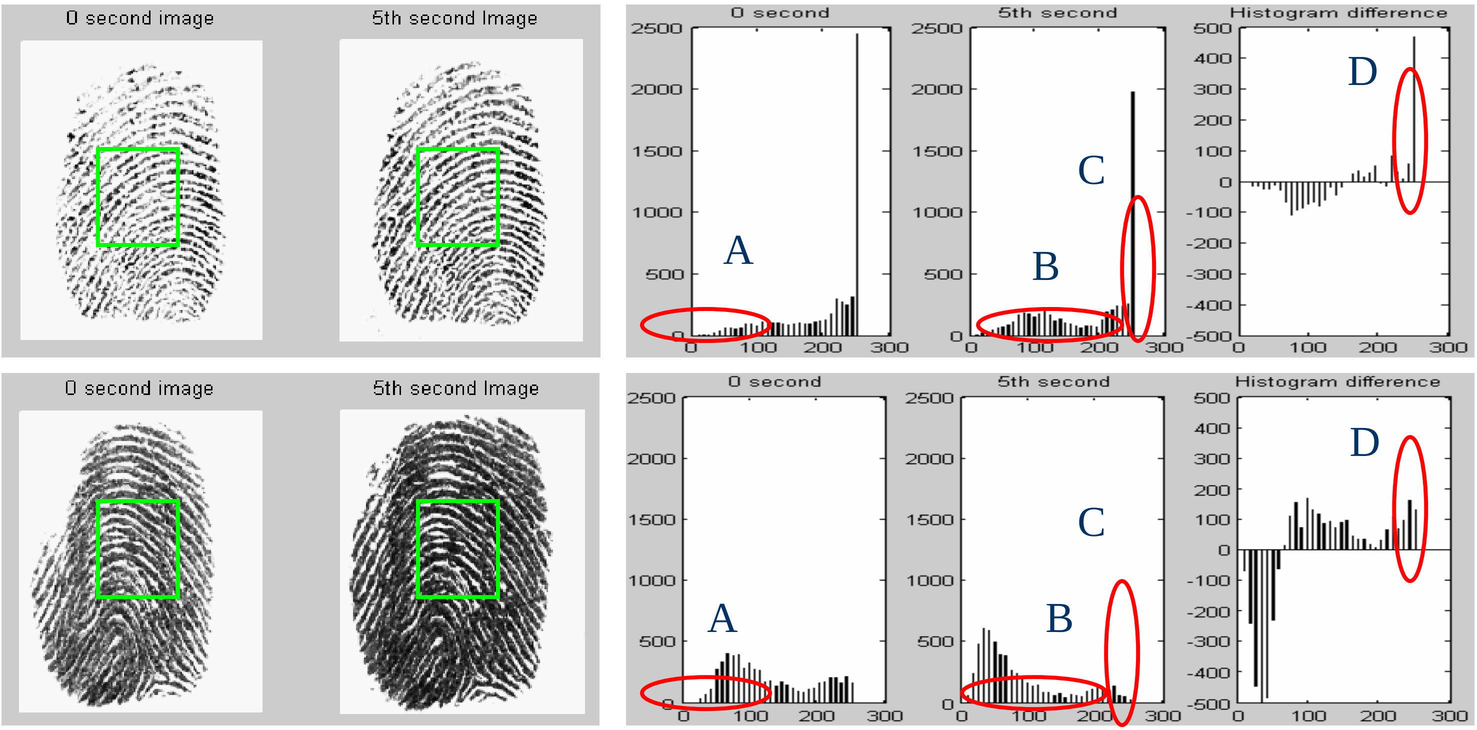
Fingerprint Sensors and Dataset

- **Fingerprint Sensors**
  - Capacitive DC: Precise Biometrics 100SC
  - Optical: Secugen FDU01
  - Electro-optical: Ethentica USB2500
- **Dataset**
  - Live: 58
  - Spoof: 50(Play-doh and gelatin)
  - Cadaver: 28
  - Training (4/9), validation(2/9) and test(1/3) set

Precise: Features Extraction

Live

Spoof



$$H1\_before = A = \sum_{i=1}^{100} h1(i)$$

$$Ratio = \frac{C}{B} = \frac{\sum_{i=246}^{256} h2(i)}{(\sum_{i=1}^{245} h2(i) + 0.1)}$$

$$Dif\_256 = D = \sum_{i=246}^{256} | h1(i) - h2(i) |$$

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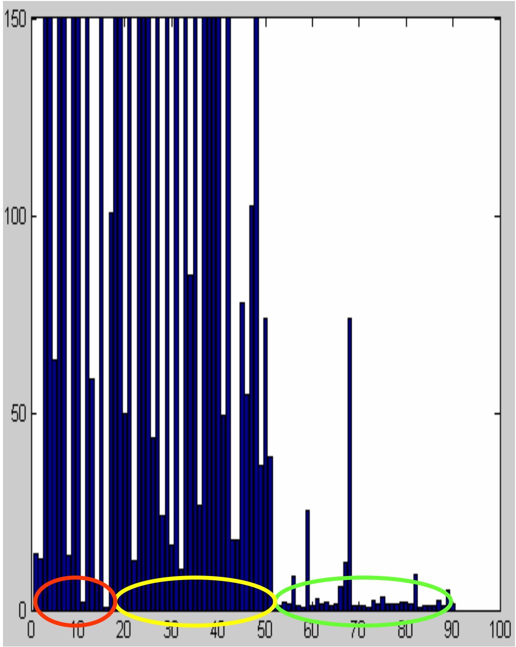
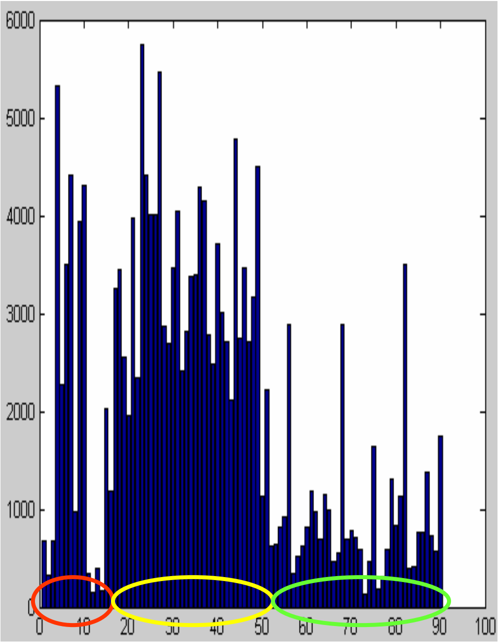
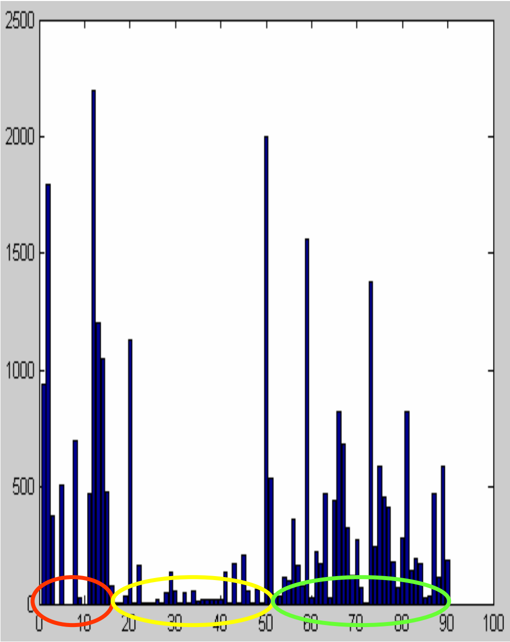
Precise: Features Extraction







Cadaver Spoof Live

Ratio

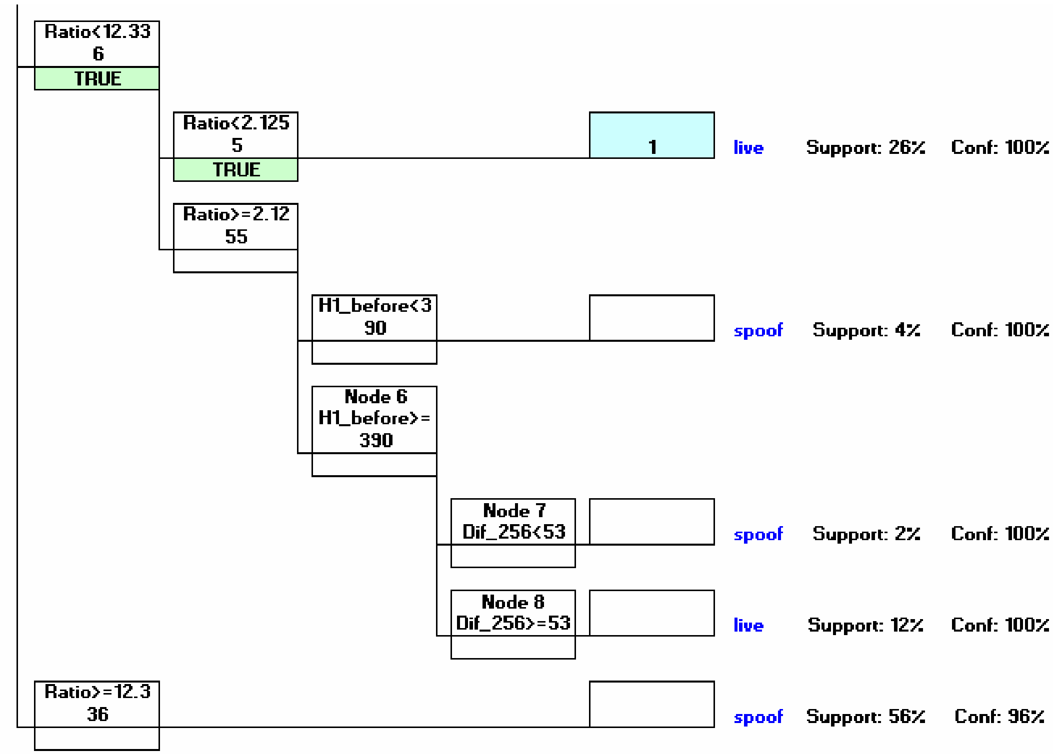
Cadaver Spoof Live

H1_before

Cadaver Spoof Live

Dif_256

Precise: Classification Tree and Results



Training Data

True Class	Predicted Class: live	Predicted Class: spoof	
live	19	1	20
spoof		30	30
	19	31	50

Validation Data

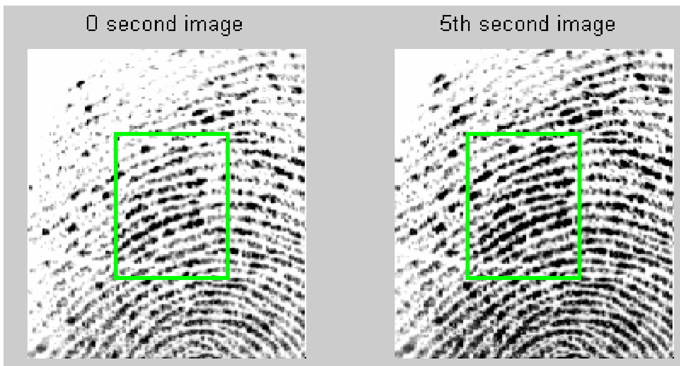
True Class	Predicted Class: live	Predicted Class: spoof	
live	16	2	18
spoof	1	20	21
	17	22	39

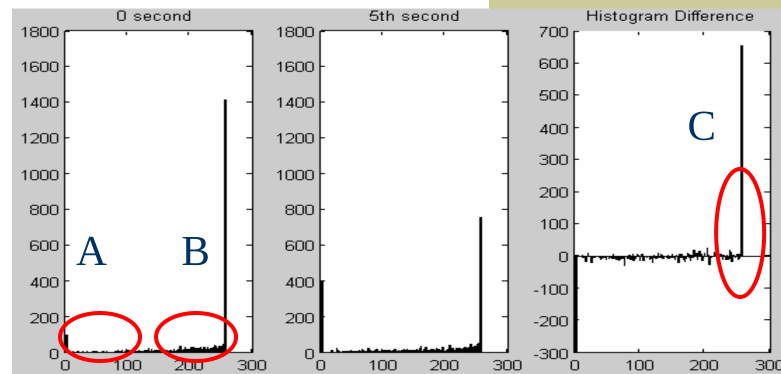
Test Data

True Class	Predicted Class: live	Predicted Class: spoof	
live	20		20
spoof		32	32
	20	32	52

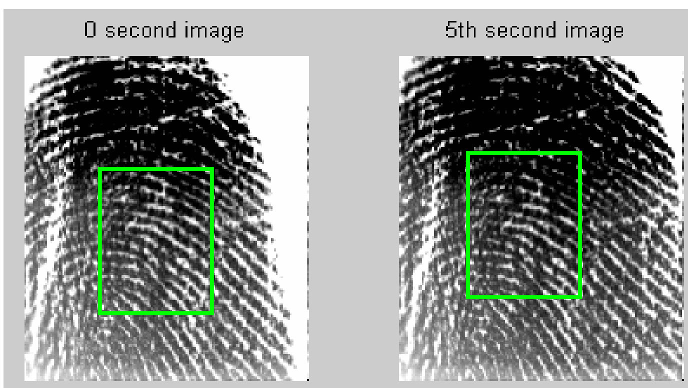
Secugen: Features Extraction

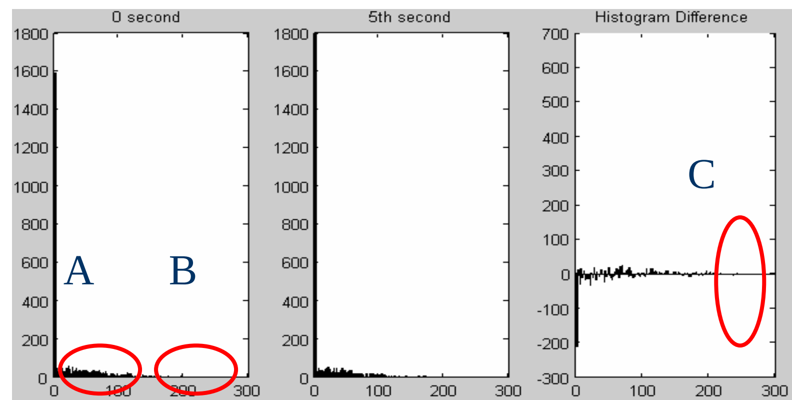
Live





Spoof



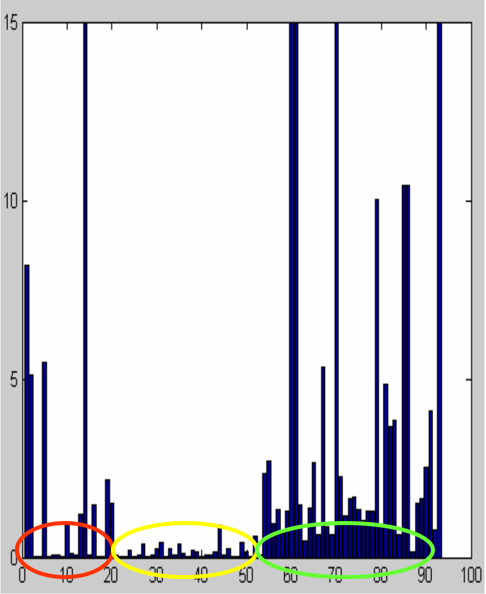


$$\text{Ratio} = \frac{B}{A} = \frac{\sum_{i=150}^{254} h1(i)}{\left(\sum_{i=1}^{149} h1(i) + 0.1\right)}$$

$$\text{H1\_behind} = B = \sum_{i=150}^{254} h1(i)$$

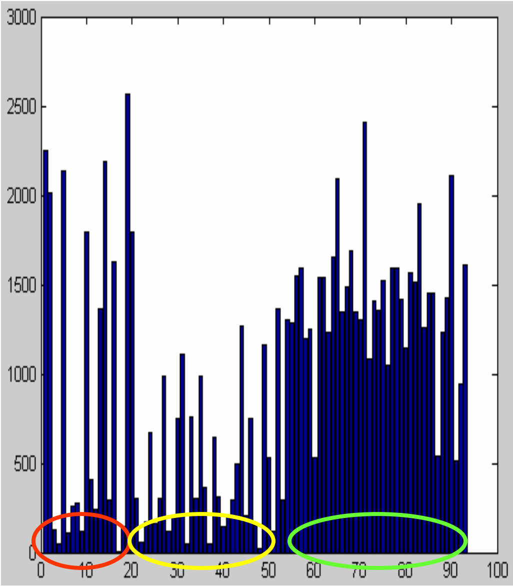
$$\text{Dif\_256} = C = \sum_{i=255}^{256} |h1(i) - h2(i)|$$

Secugen: Features Comparison



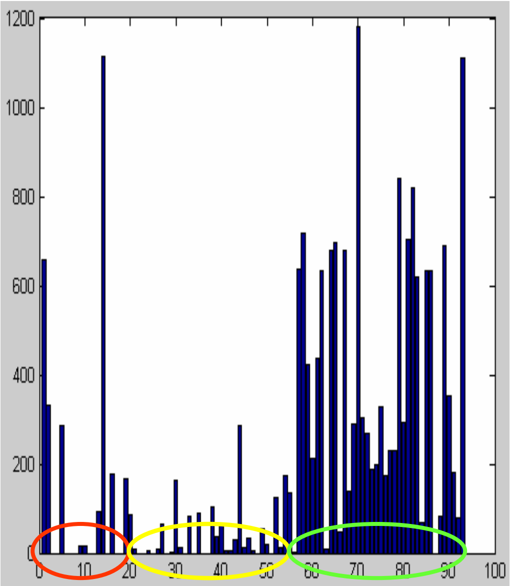
Cadaver Spoof Live

Ratio



Cadaver Spoof Live

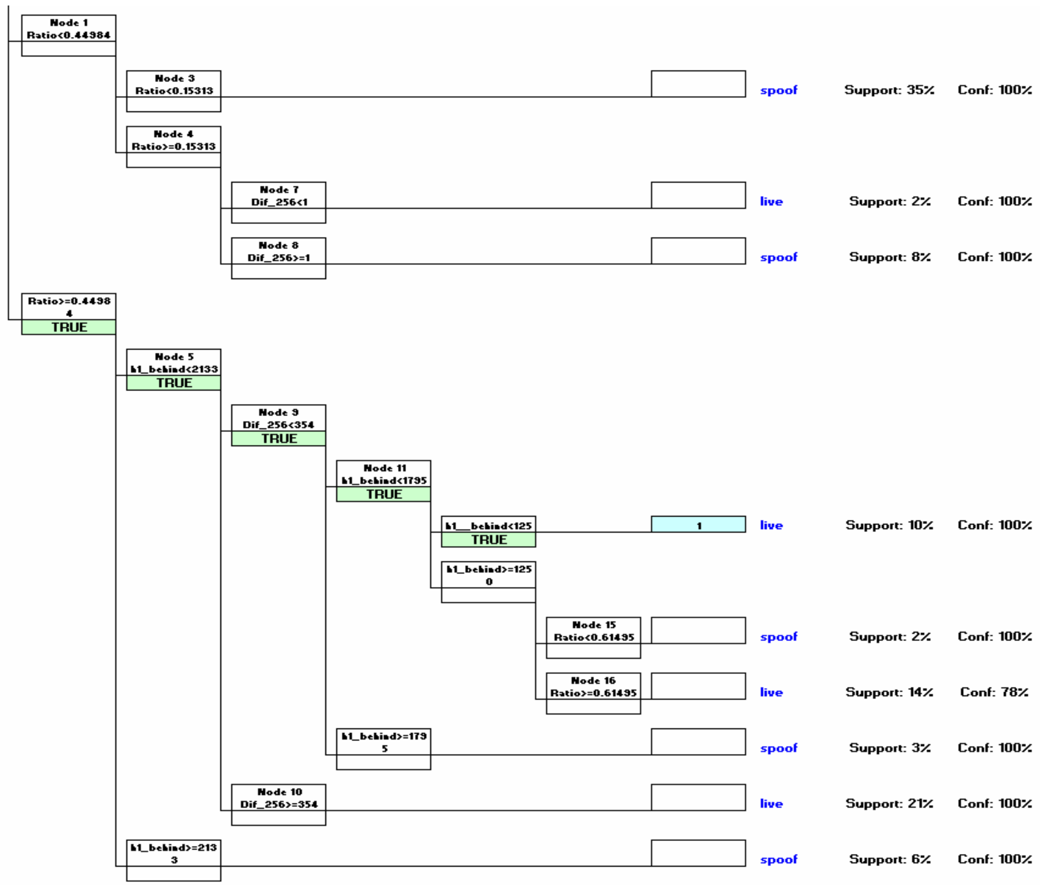
H1_behind



Cadaver Spoof Live

Dif_256

Secugen: Classification Tree and Results



Training Data

	Predicted Class		
True Class	live	spoof	
live	24		24
spoof	2	34	36
	26	34	60

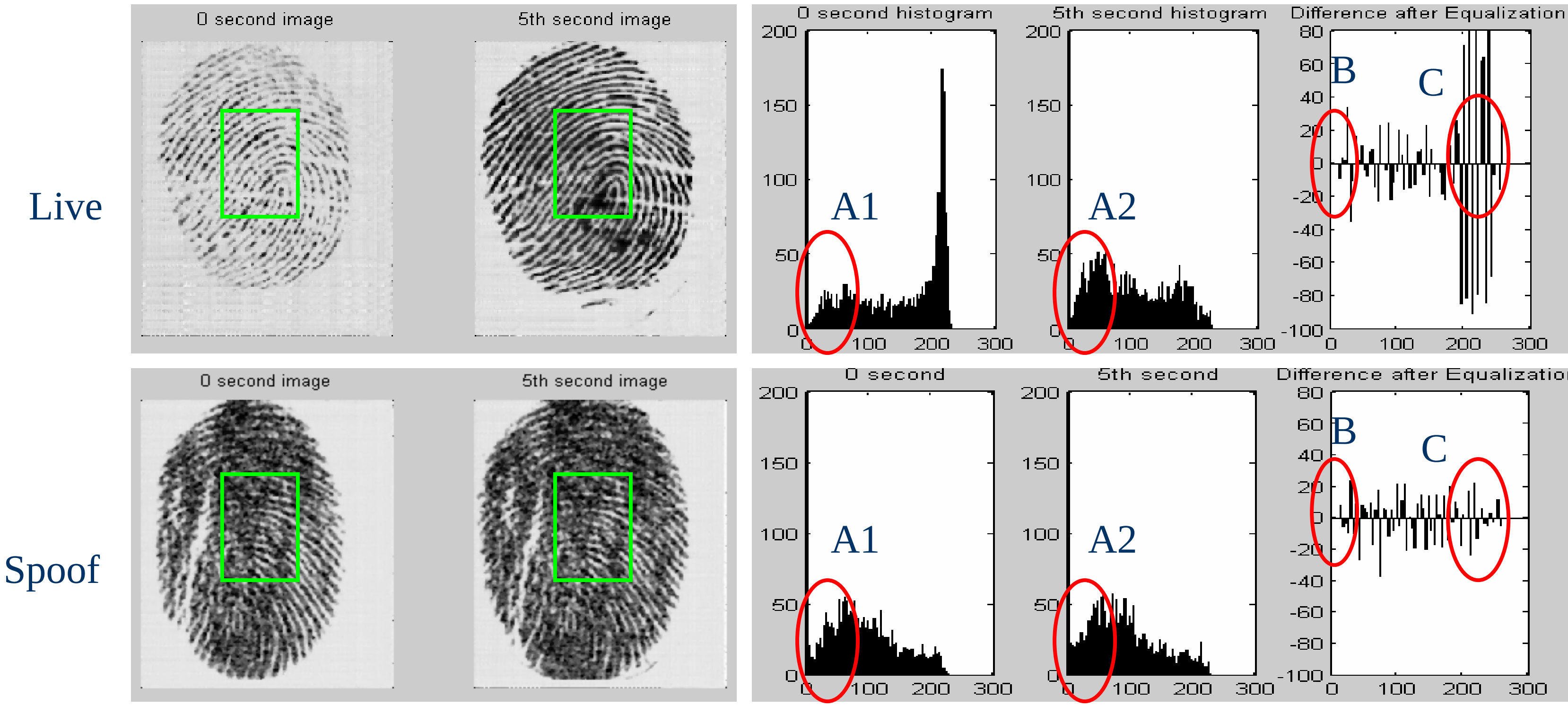
Validation Data

	Predicted Class		
True Class	live	spoof	
live	13	1	14
spoof	1	16	17
	14	17	31

Test Data

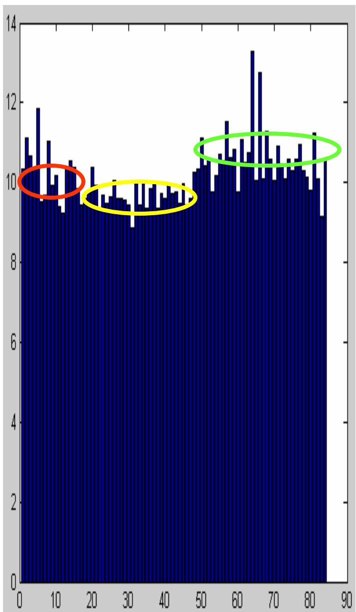
	Predicted Class		
True Class	live	spoof	
live	18	2	20
spoof	2	23	25
	20	25	45

Ethentica: Features Extraction



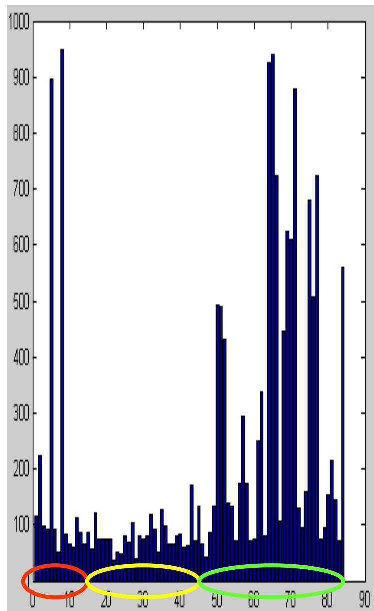
$$\mathrm{Dev} = std(\mathrm{h2}(i)) \quad \mathrm{P\_before} = \frac{\mathrm{A1}}{\mathrm{A2}} = \frac{\sum_{i=1}^{80} \mathrm{h1}(i)}{\sum_{i=1}^{80} \mathrm{h2}(i)} \quad \mathrm{Dif\_0} = \mathrm{B} = \sum_{i=1}^{10} |\mathrm{h1}(i) - \mathrm{h2}(i)| \quad \mathrm{Dif\_256} = \mathrm{C} = \sum_{i=200}^{250} |\mathrm{h1}(i) - \mathrm{h2}(i)|$$

Ethentica: Features Comparison



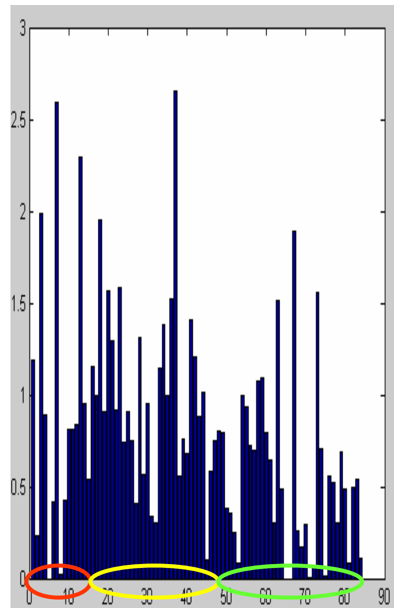
Cadaver Spoof Live

Dev



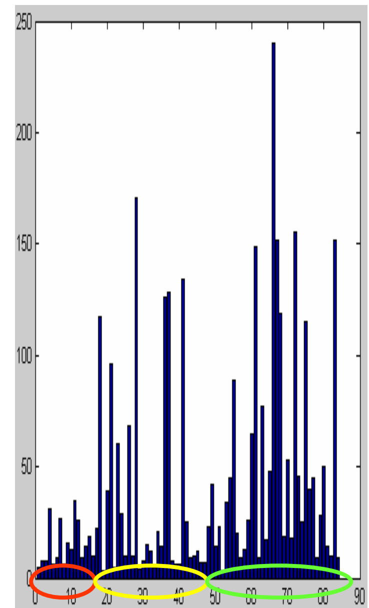
Cadaver Spoof Live

Dif_256



Cadaver Spoof Live

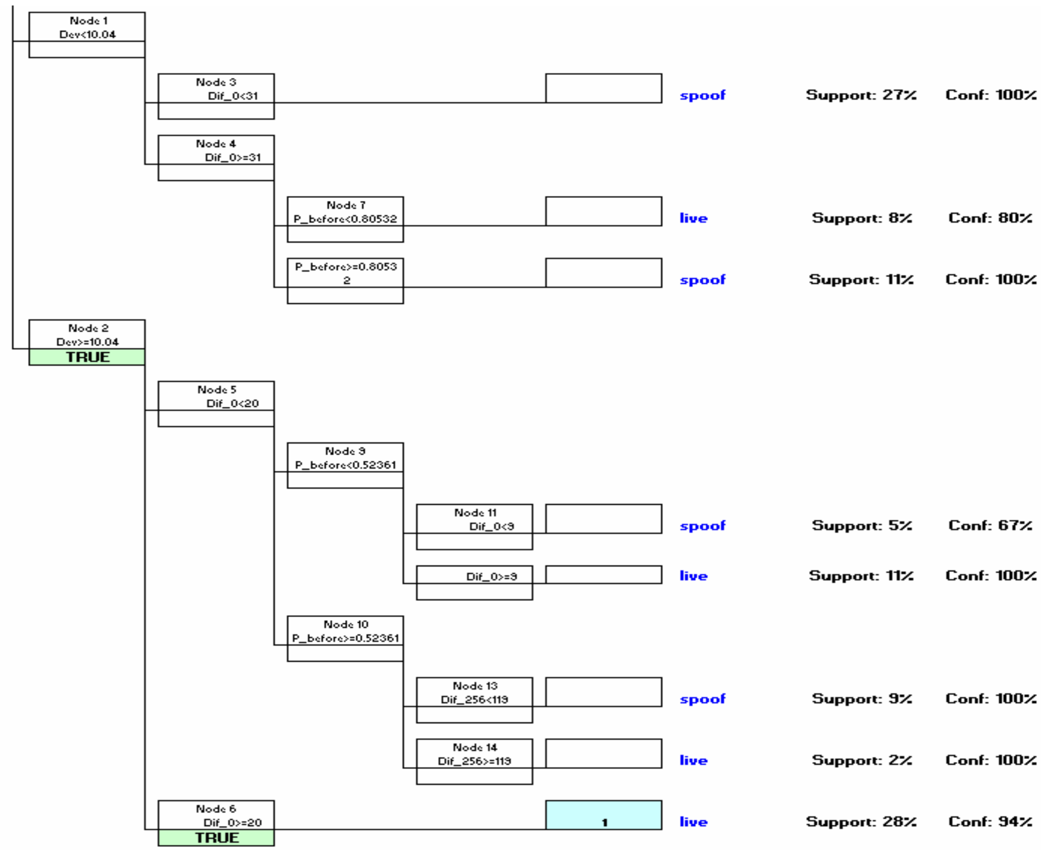
P_before



Cadaver Spoof Live

Dif_0

Ethentica: Classification Tree and Results



Training Data

	Predicted Class		
True Class	live	spoof	
live	29	1	30
spoof	2	32	34
	31	33	64

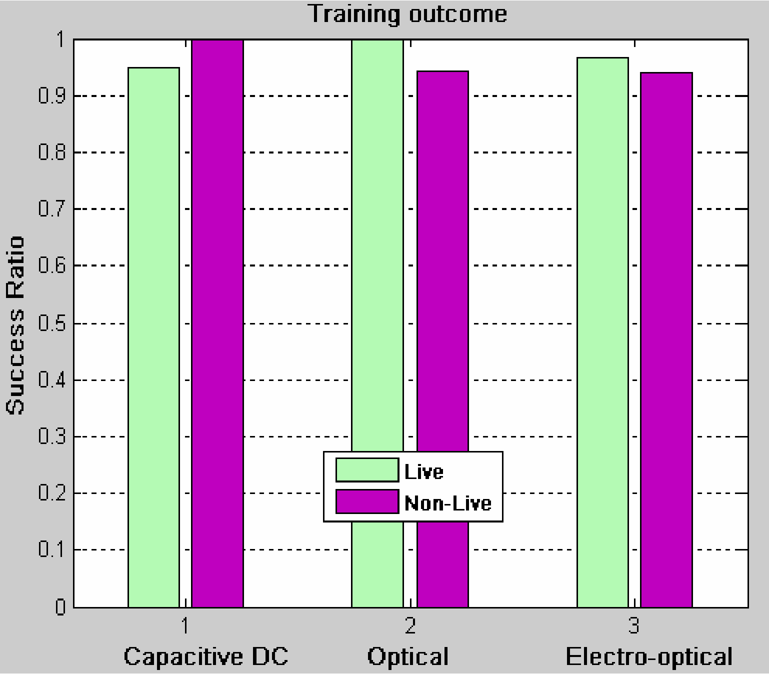
Validation Data

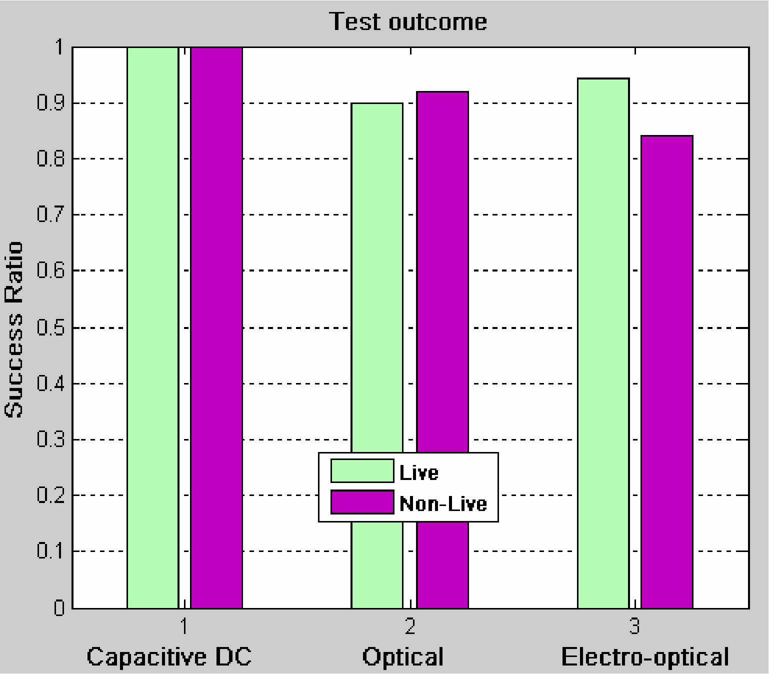
	Predicted Class		
True Class	live	spoof	
live	7		7
spoof	1	12	13
	8	12	20

Test Data

	Predicted Class		
True Class	live	spoof	
live	17	1	18
spoof	4	21	25
	21	22	43

Outcome Summary





- Success ratio: 84%~100%
- Grey level differences are specific to the type of spoof images we collected

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Conclusion and Future Work

- Intensity based approach
  - Static and dynamic features are extracted to quantify gray level differences
- Classification tree
- Simple, efficient and saving time
- Purely software based
- Anti-spoofing protection for fingerprint scanners
- Future work
  - Consider other methods to defeat liveness algorithm
  - Study existence of perspiration pattern over larger number of subjects

Thank You

Questions ?