Evaluation of Fingerprint Readers: Environmental factors, Human Factors, & Liveness detecting capability

Hale Kim

hikim@inha.ac.kr

School of Information & Communication Engineering

INHA UNIVERSITY

Biometrics Engineeri Research Center

YONSE

Research Purpose & Scope

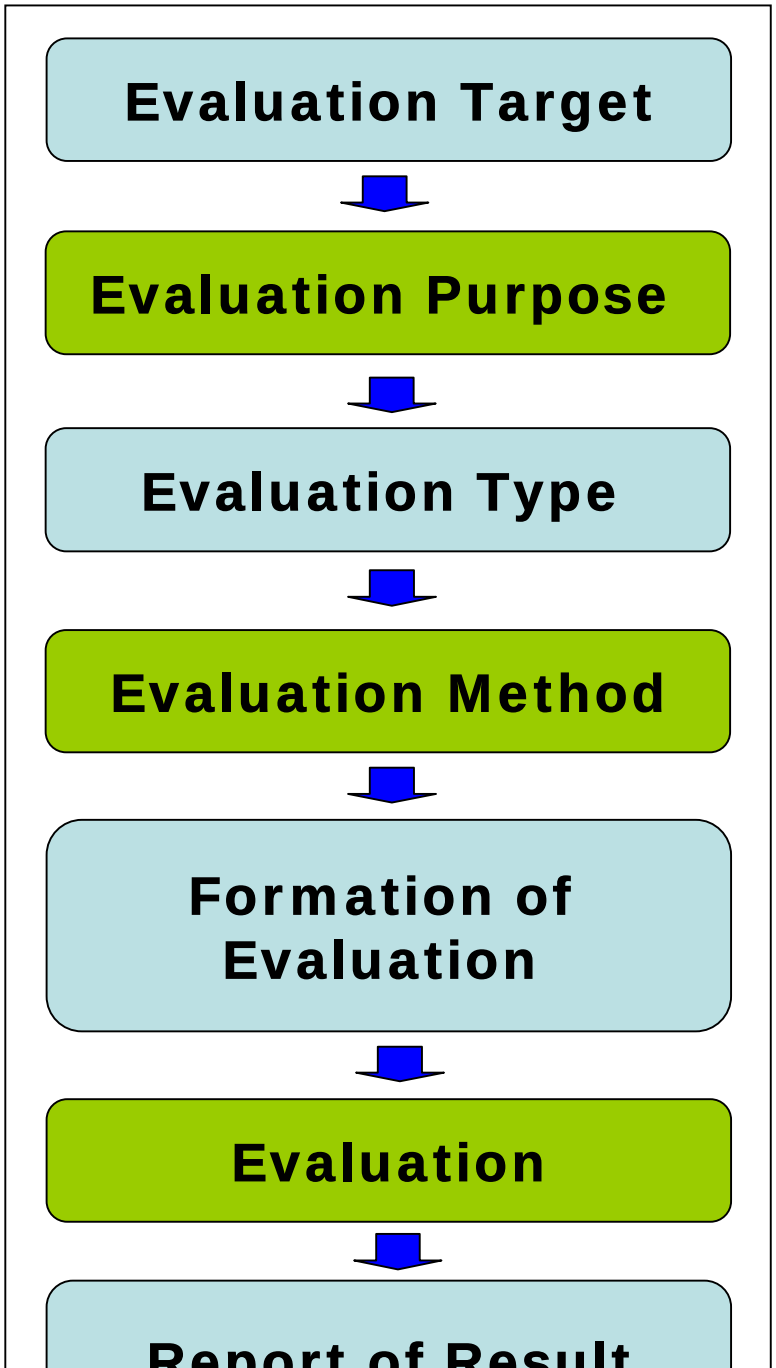
Purpose

- To study comparatively on characteristics of fingerprint readers of various sensing mechanisms
- To provide a framework of evaluating the performance of fingerprint readers

Scope

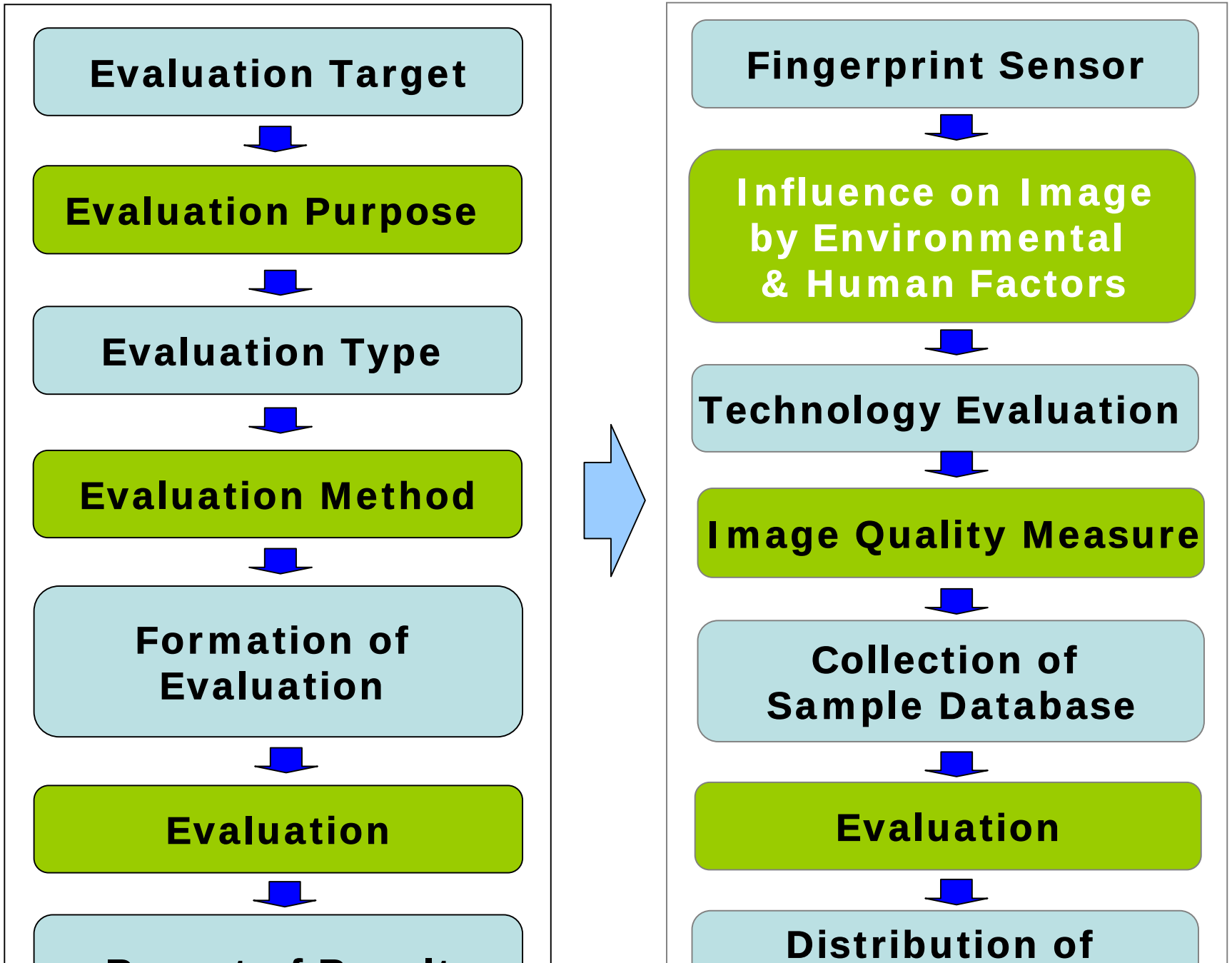
- Quantitative assessment of fingerprint image quality according to environmental as well as human factors
- Test of liveness detection using gummy finger and silicon fingers

Evaluation Framework



- Simplified framework for evaluating biometrics products

Experiment I



Evaluation Targets

Type / m	Optical	Semi-conductor	Tactile	Therm
DPI	500	250	400	500
eness tection	No	Yes	No	No
erating mp	0~40℃	-20~70℃	0~50℃	0~70°
ample mage				

Evaluation Purpose: Effect of influencing factors

Factor			States
Environment	Temperature (°C)	Below 0	Winter
		0~10	Beginning of Spring or end of Fall
		10~20	Spring or fall
		20~30	Room Temperature
		Above 30	Summer
	Humidity		20 ~ 60%
Human	Pressure	Low	Softly pressing
		Middle	Normally pressing
		High	Strongly pressing
	Skin Humidity	Low	0 ~ 35%
		Middle	36 ~ 70%
		High	71 ~ 100%

Evaluation Method: Quality of fingerprint image

Why do we need to measure the quality of fingerprint image?

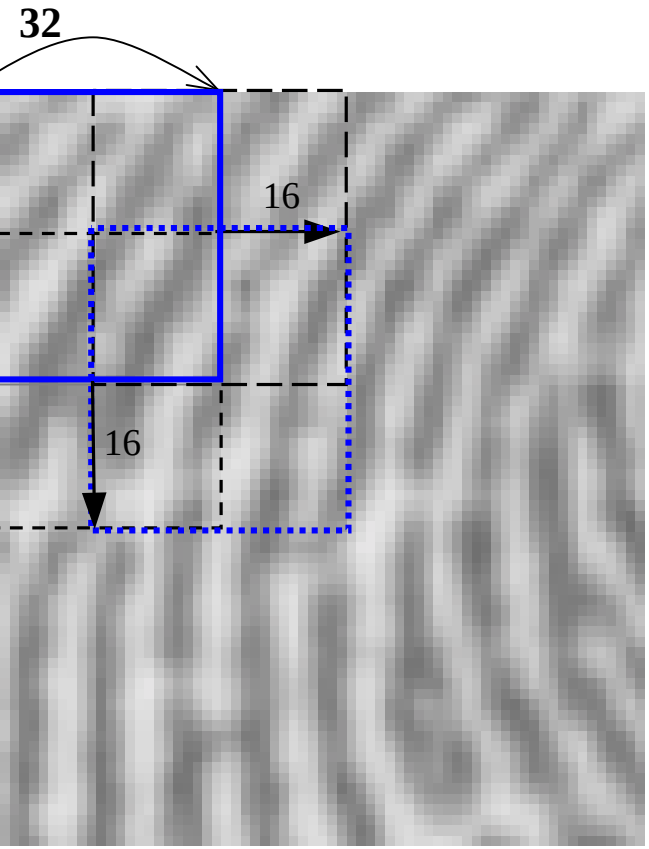
- It affects the performance of feature extraction.
- It is often utilized for failure-to-enroll or failure-to-acquire.
- It indicates the performance of fingerprint readers according to changes in user behavior and environment.

Subjective criteria of quality of fingerprint image

- How distinctively ridges and valleys appear in gray levels.
- How apparent ridge directions are.
- How large the portion of foreground is compared to the background.

Measure of Image Quality(1)

Variance of Gray levels



$$V_k = \sqrt{\frac{1}{64}\sum_{x=1}^{32}\sum_{y=1}^{32}\left(G_{xy} - \overline{G_i}\right)^2} \qquad (k = 1,\ldots, N)$$

G_{xy} : gray value of pixel at (x, y)

$\overline{G_k}$: gray value average of k_{th} block

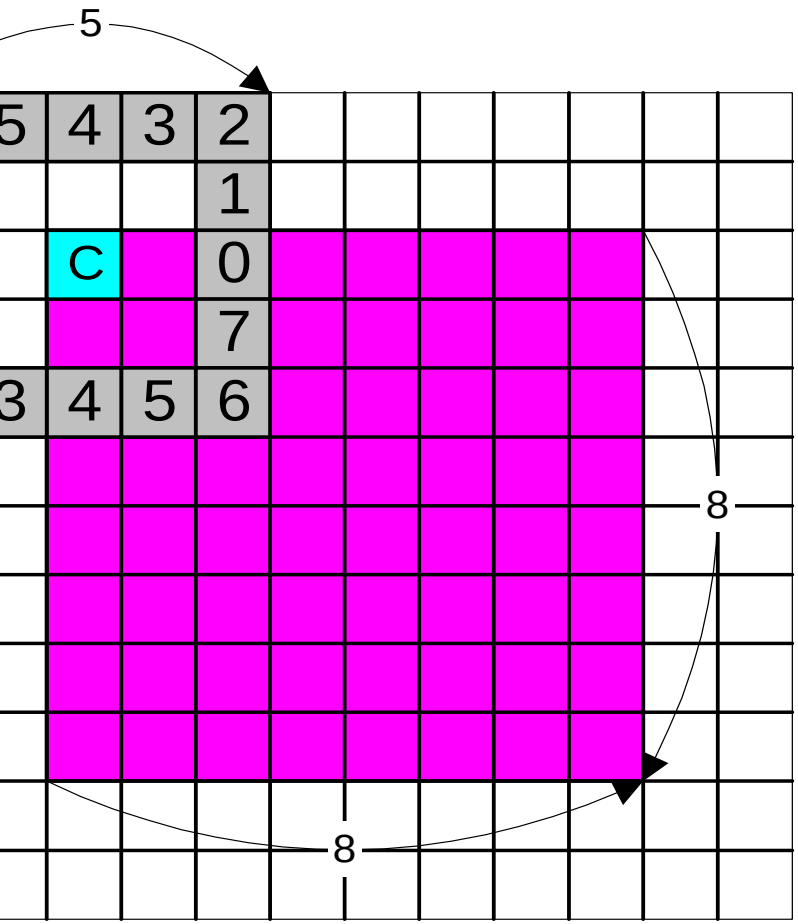
N : scan index

$$I = \frac{1}{C}\sum_{k=1}^{N} V_k \times 100$$

C : normalizing constant

Measure of Image Quality(2)

- Directional Contrast



-Directional Window

$$\theta = \min_{q}\left\{\sum_{x=1}^{8}\sum_{y=1}^{8} C_{xy}(q)\right\} \quad \text{for } q = \{0,1,\ldots,7\}$$

$C_{xy}(q)$: is the gray - value difference

$$\Theta_i = \sum_{x=1}^{8}\sum_{y=1}^{8} C_{xy}(\theta) \quad \text{and} \quad \bar{\Theta}_i = \sum_{x=1}^{8}\sum_{y=1}^{8} C_{xy}($$

θ : is the block direction. $\bar{\theta}$ is perpendicular

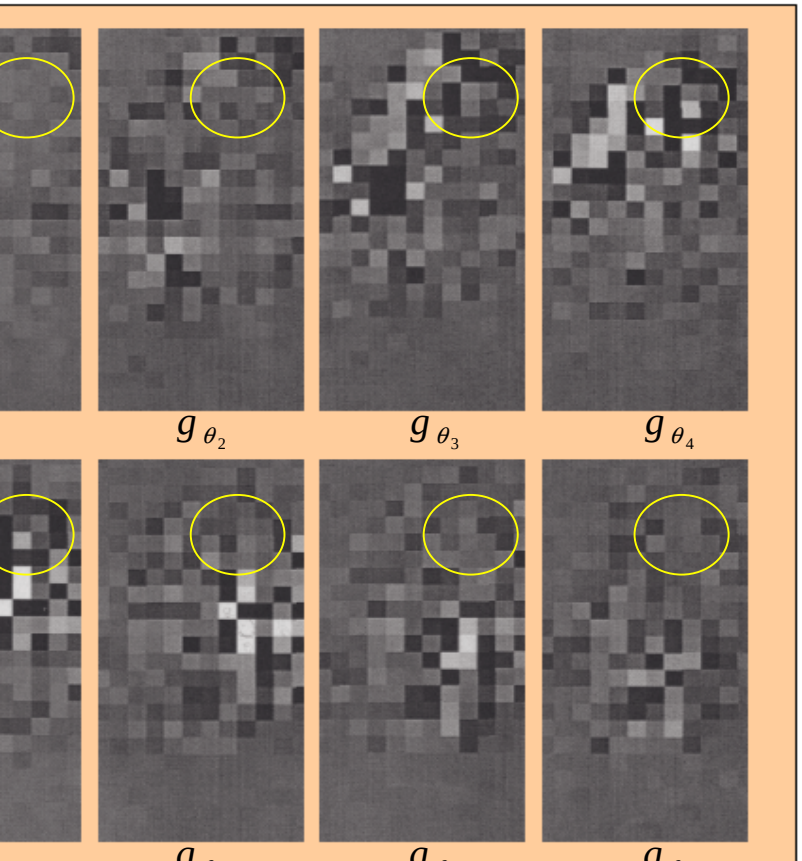
$$Q = \frac{\sum_{i=1}^{N}(\Theta_i - \bar{\Theta}_i)}{N\sum_{x=1}^{8}\sum_{y=1}^{8} C} \times 100$$

N is the total number of blocks.

C is a normalizing constant.

Measure of Image Quality(3

8-direction
Gabor filtering



- Gabor-filtered Energy

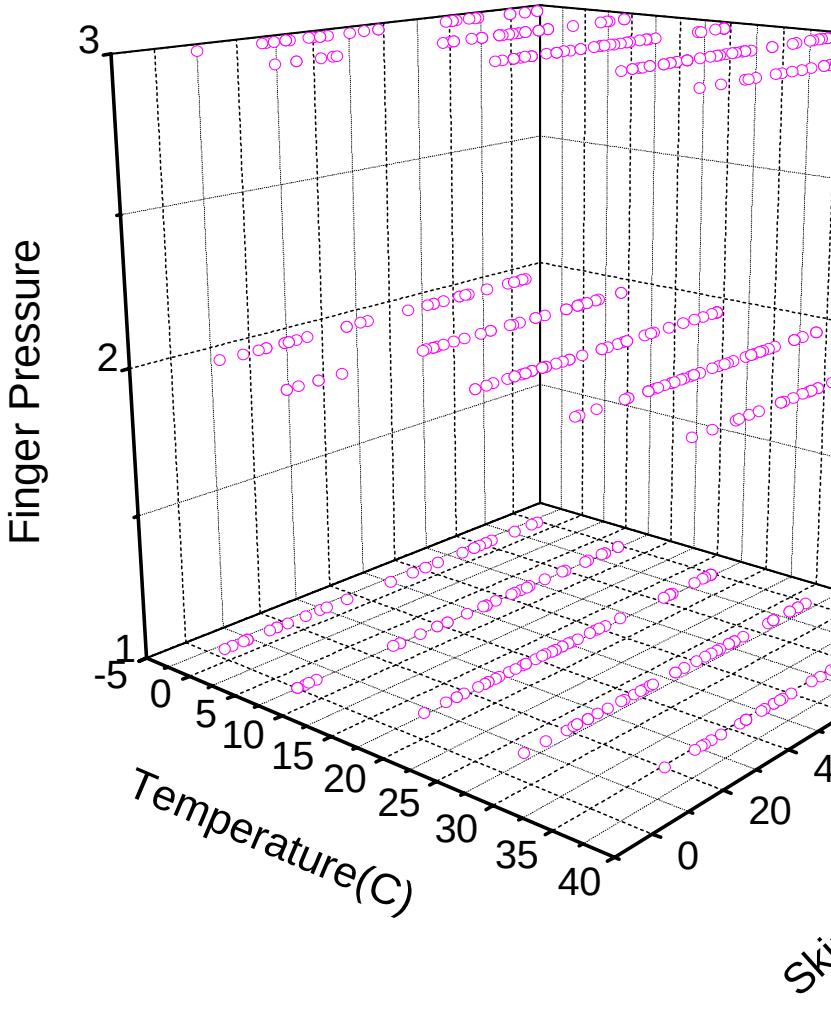
$$V_k = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(g_{\theta_i} - \overline{g_\theta})^2} \qquad \overline{g_\theta} = \frac{1}{m}\sum_{i=1}^{m}$$

$$G = \frac{1}{C}\sum_{k=1}^{N} V_k \times 100 \qquad (k = 1, \ldots, N)$$

C : normalizing constant N : scan index

Formation of Evaluation: Fingerprint database

mp(℃) dity(%)	No. of Human	Number of Images			
		Optical	Semi-con	Tactile	Thermal
3/27	5	90	90	90	90
/32	6	108	108	108	108
3/58	8	144	144	144	144
7/40	7	126	126	126	126
2/43	7	126	126	126	126
tal	33	594	594	594	594



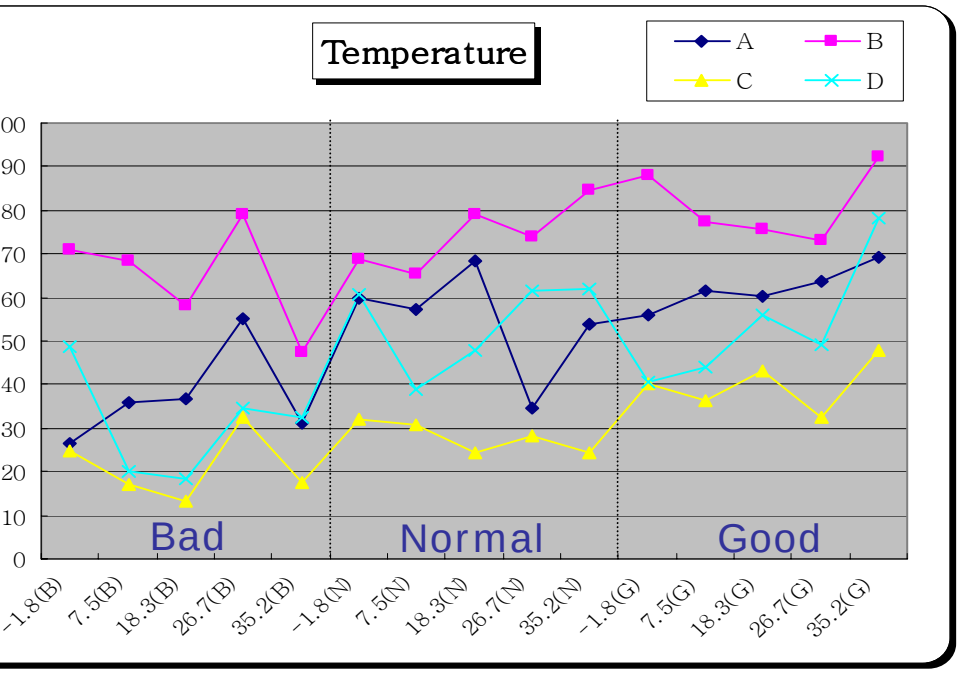
Optical sensor

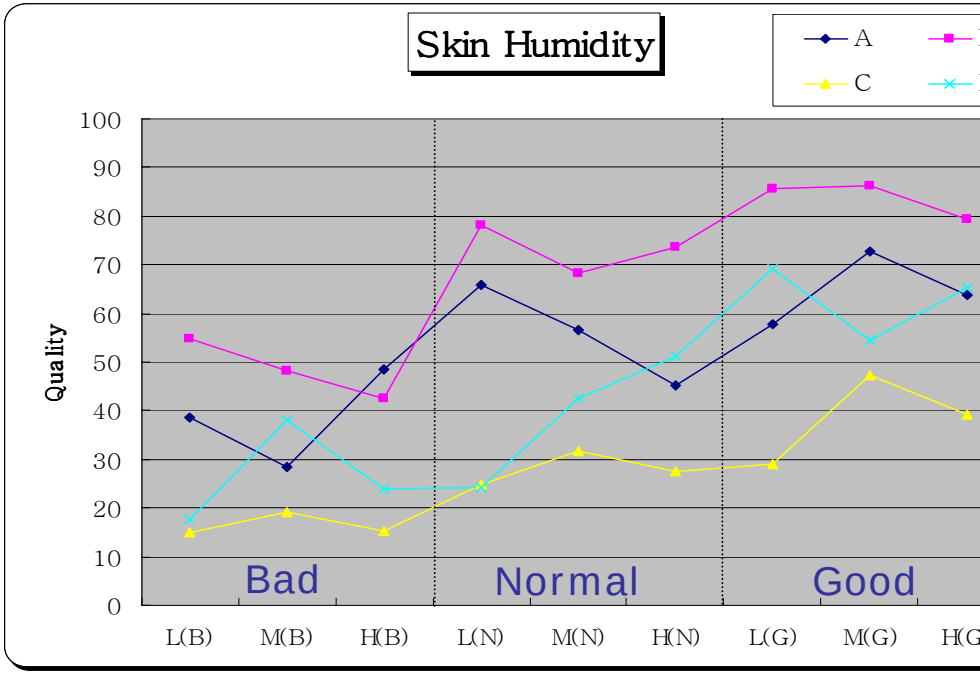
Example of Visual Inspection

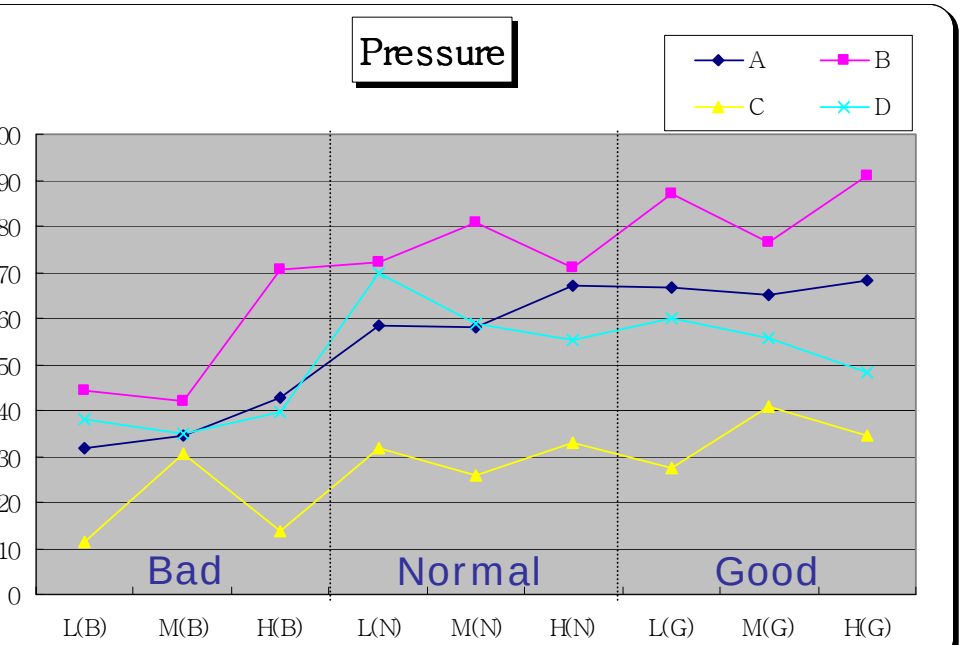
Skin Humidity : 35%~70% (Semiconductor Type

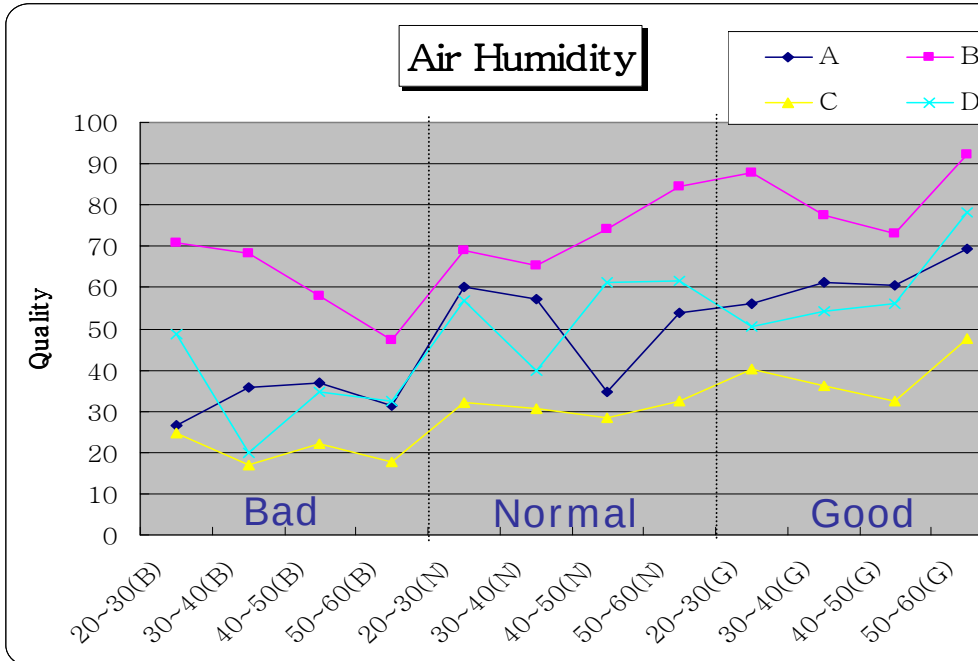
Quality	Bad	Normal	Good
Quality easure (DC)	29	66	68
Sample Image			

Visual Inspection for assurance of quality measures

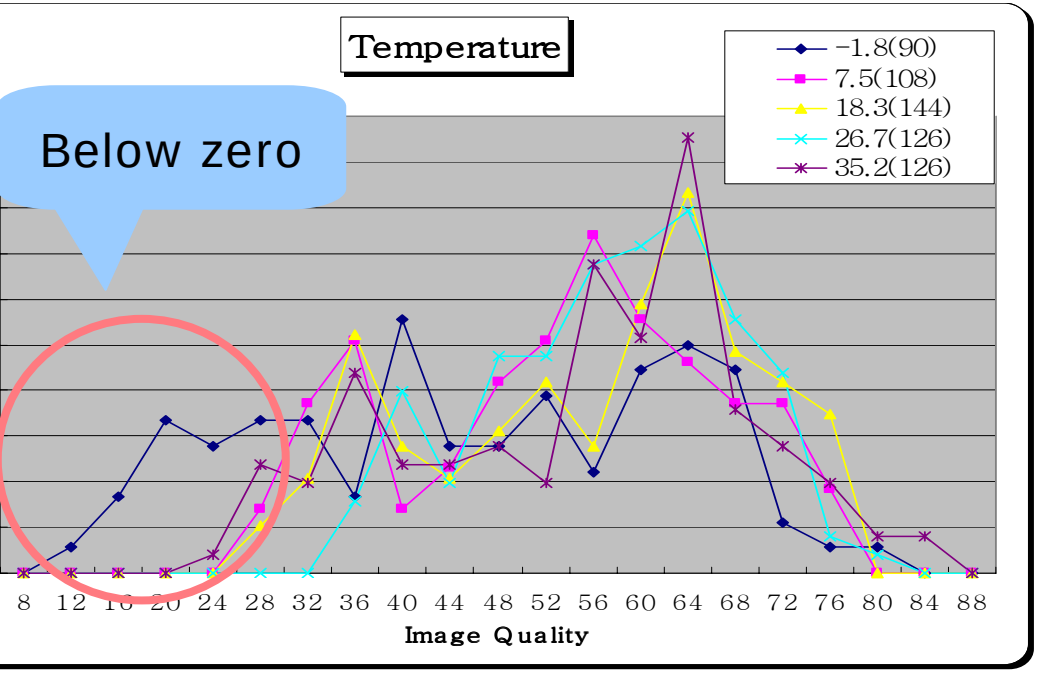


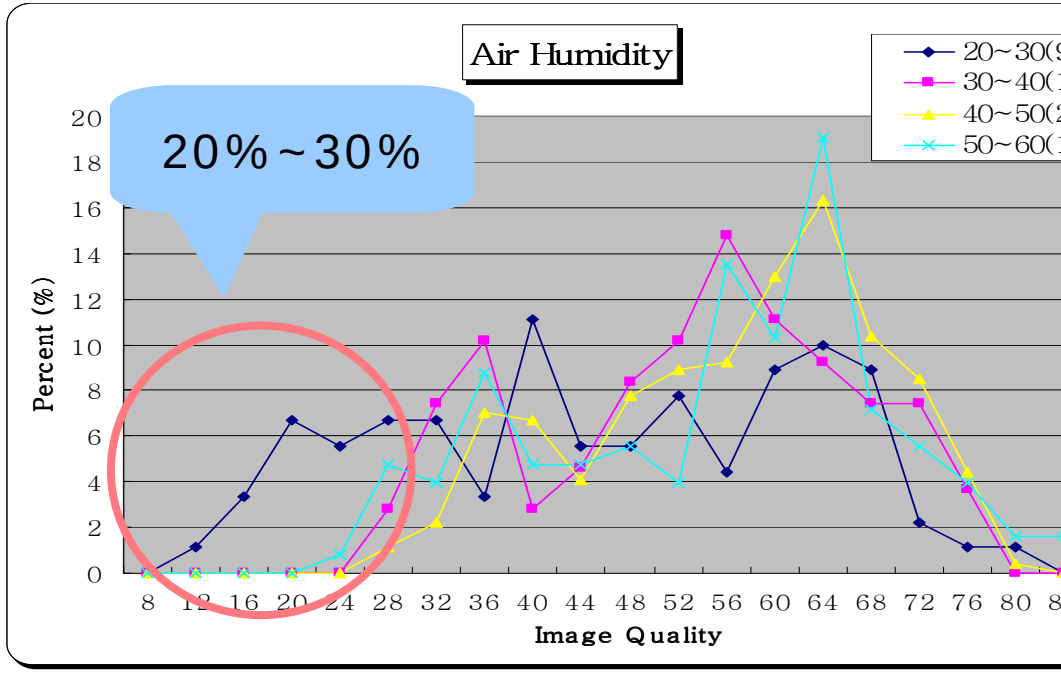


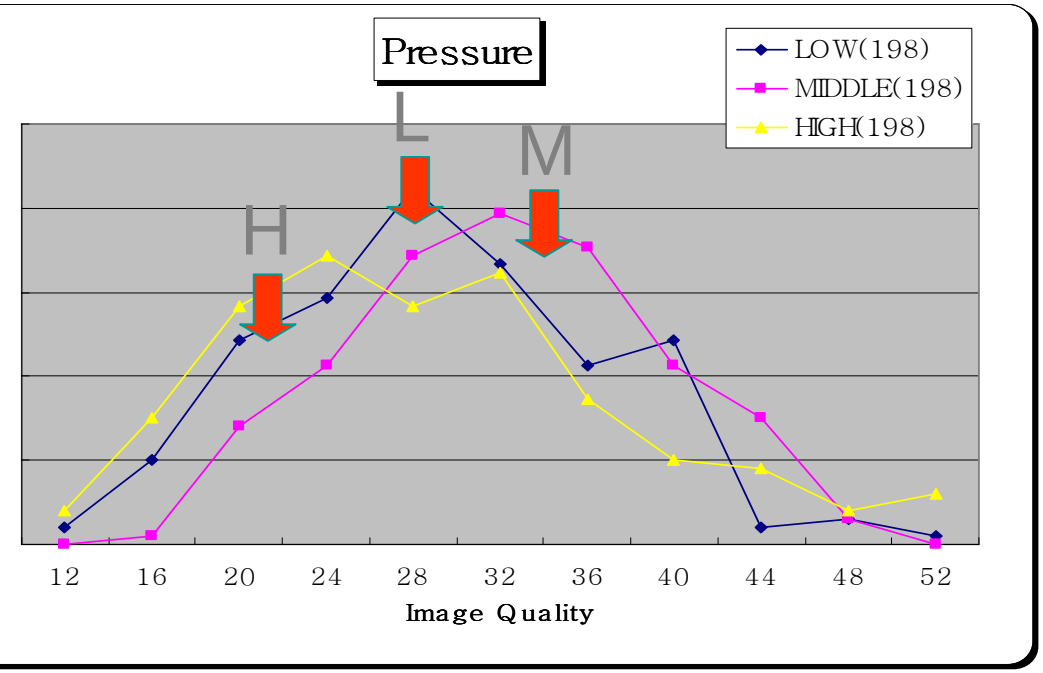


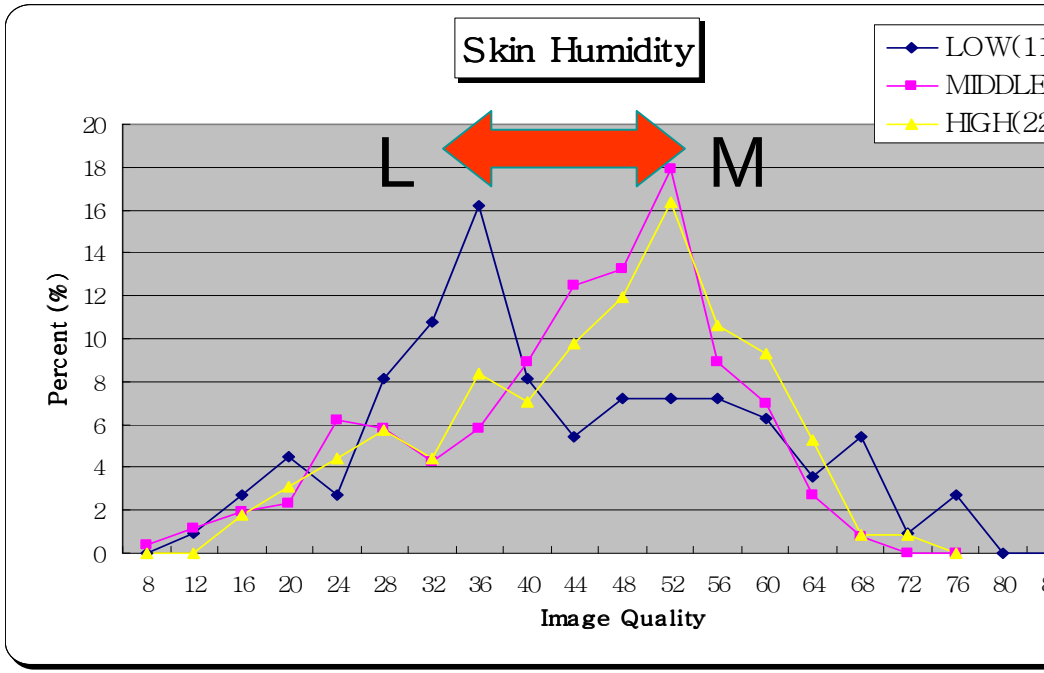


Influence on Optical sensor

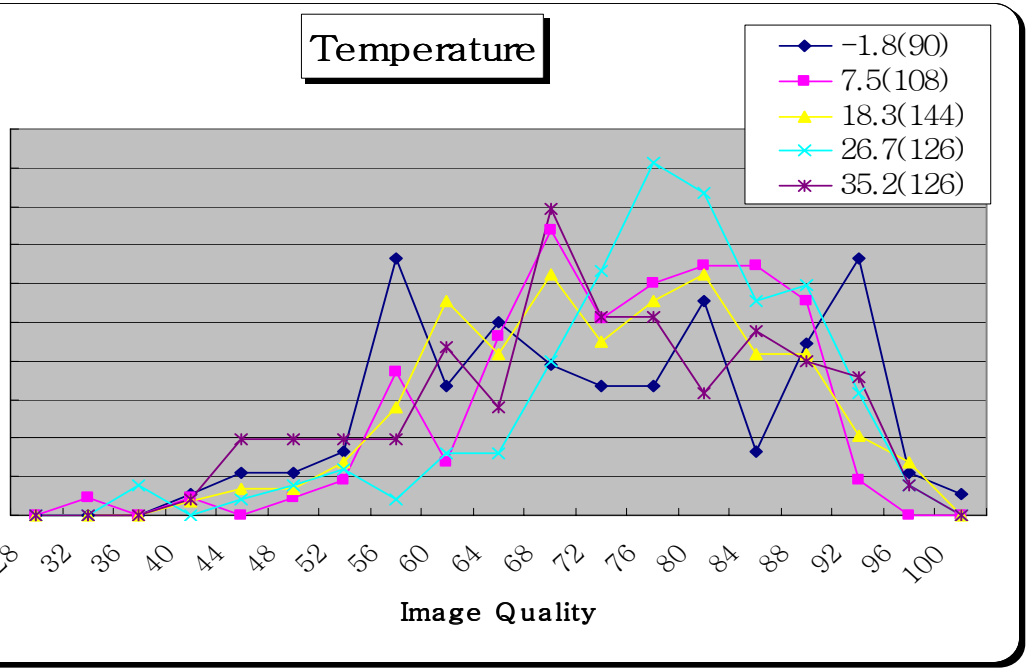


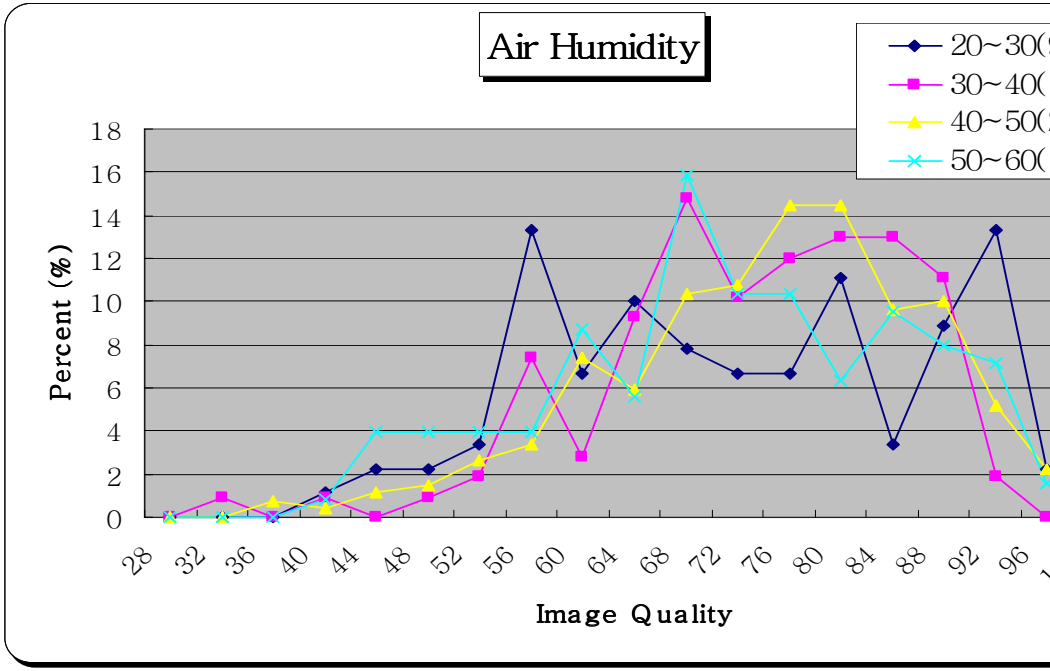


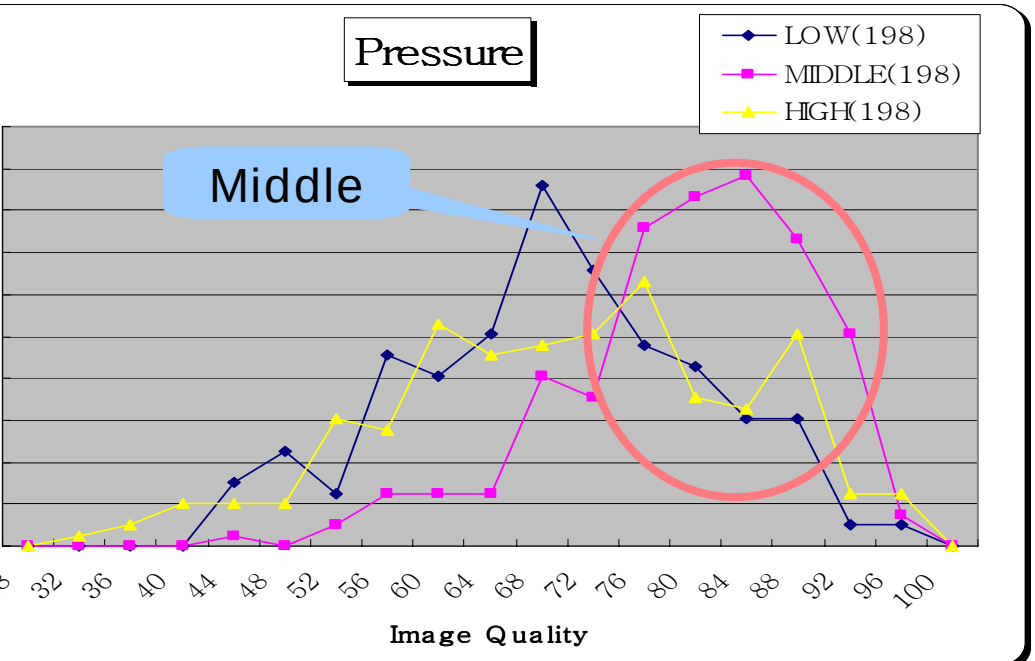


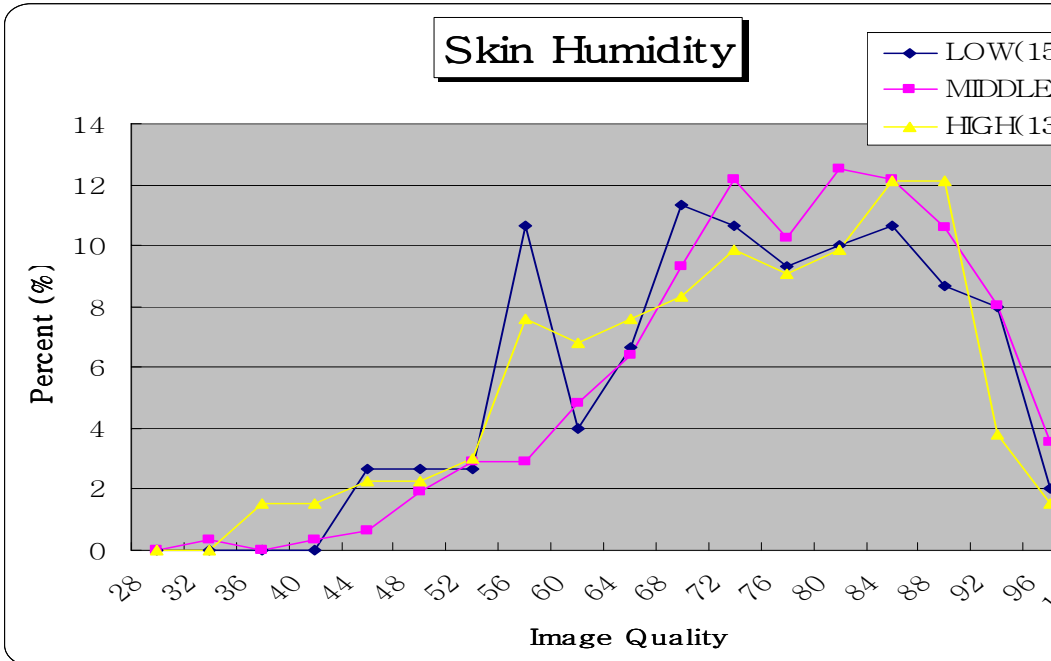


Influence on Semiconductor Sensor

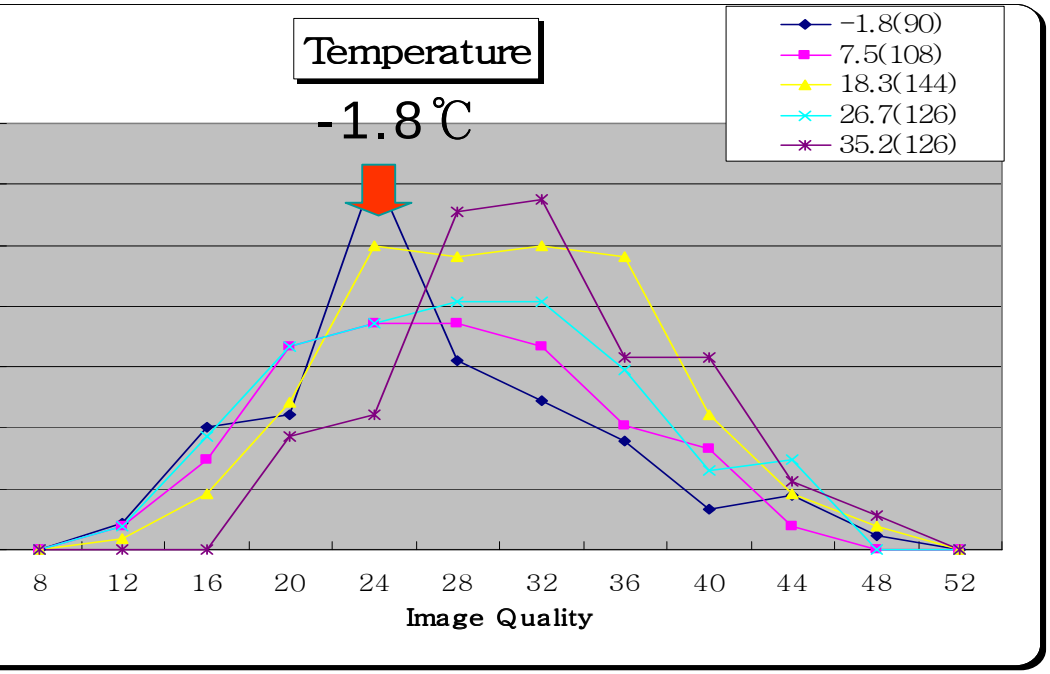


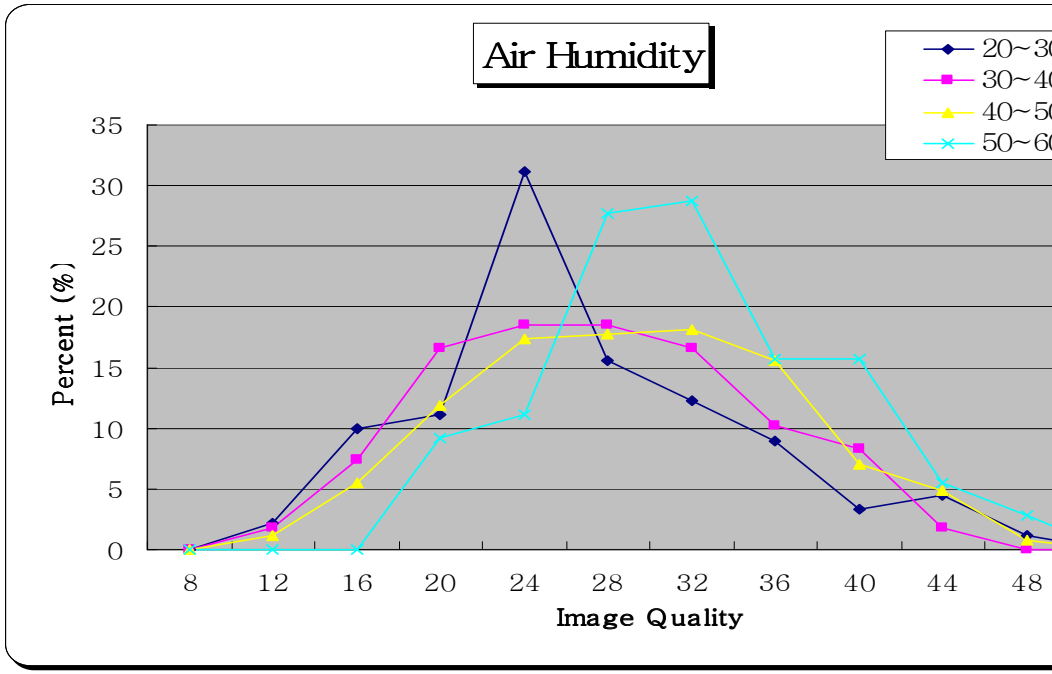


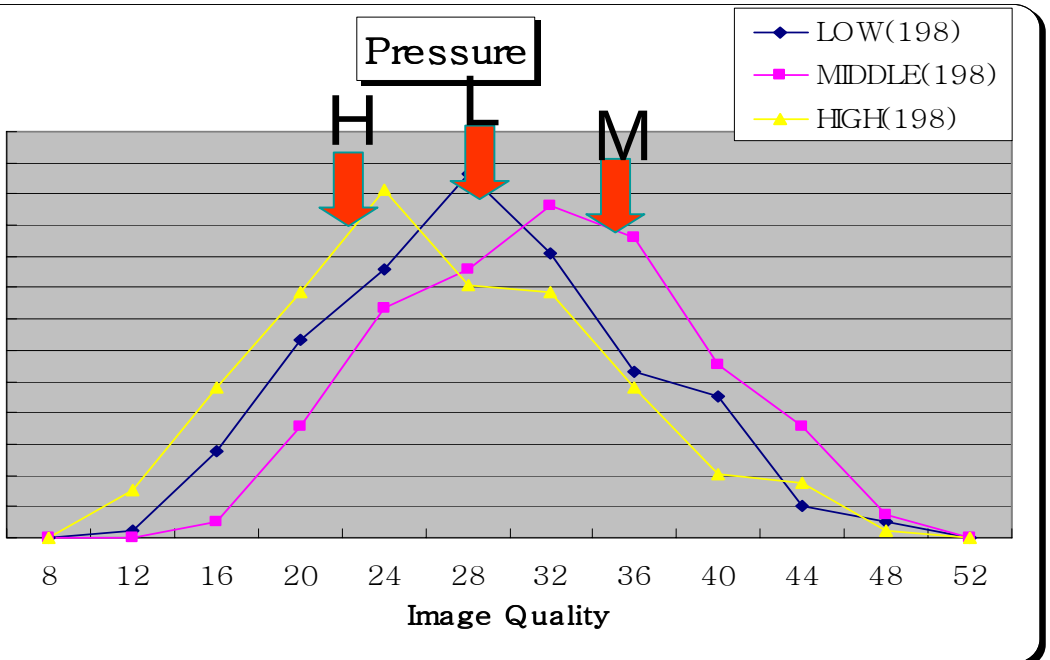


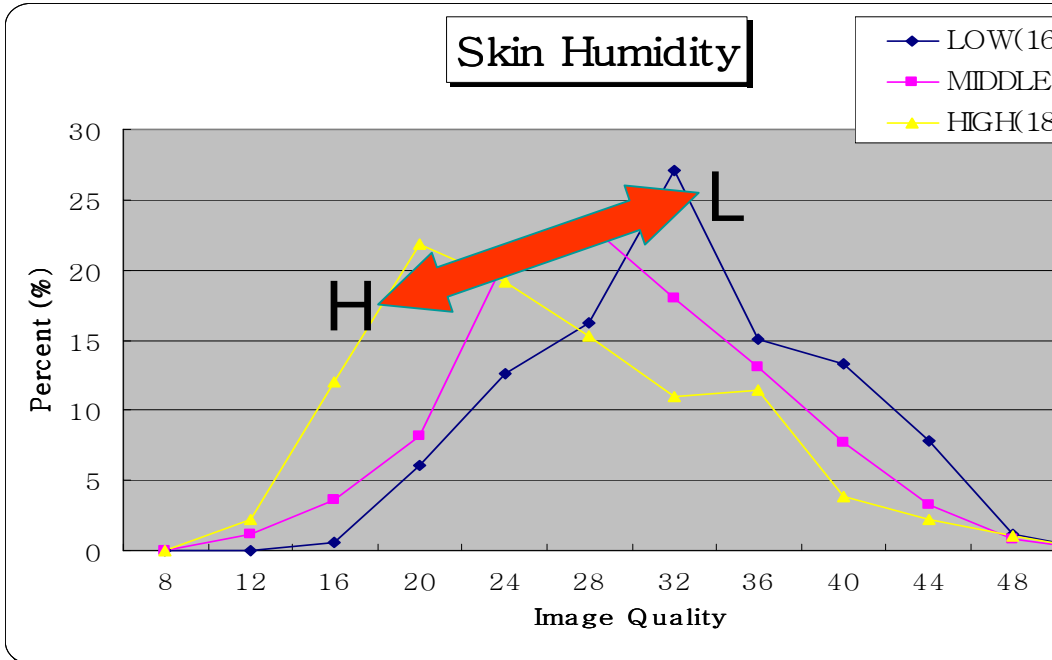


Influence on Tactile Sensor

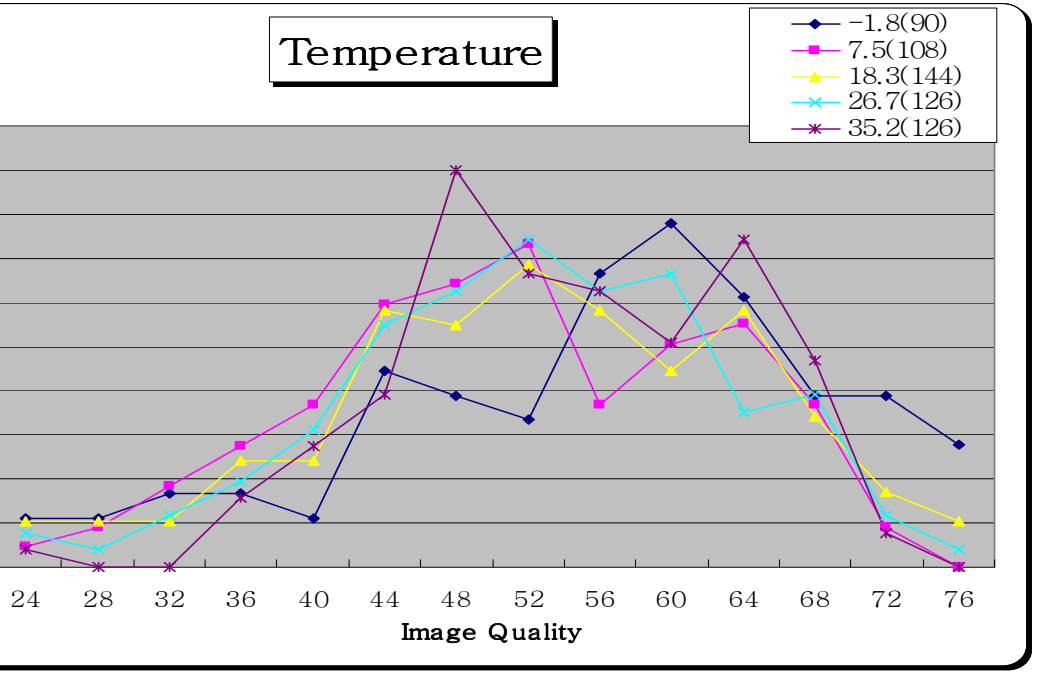


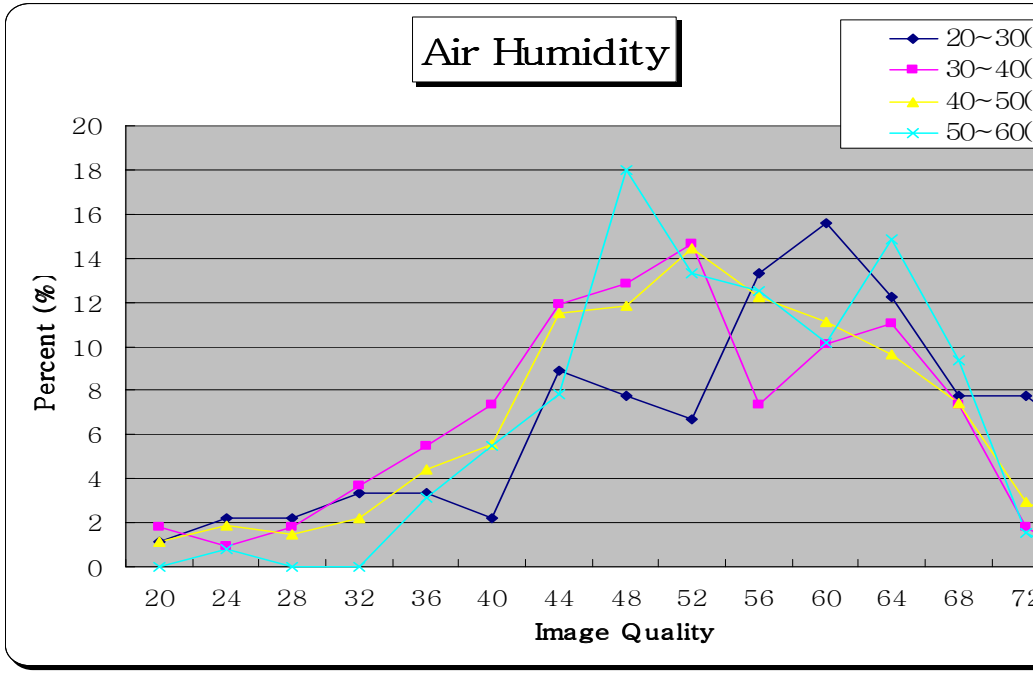


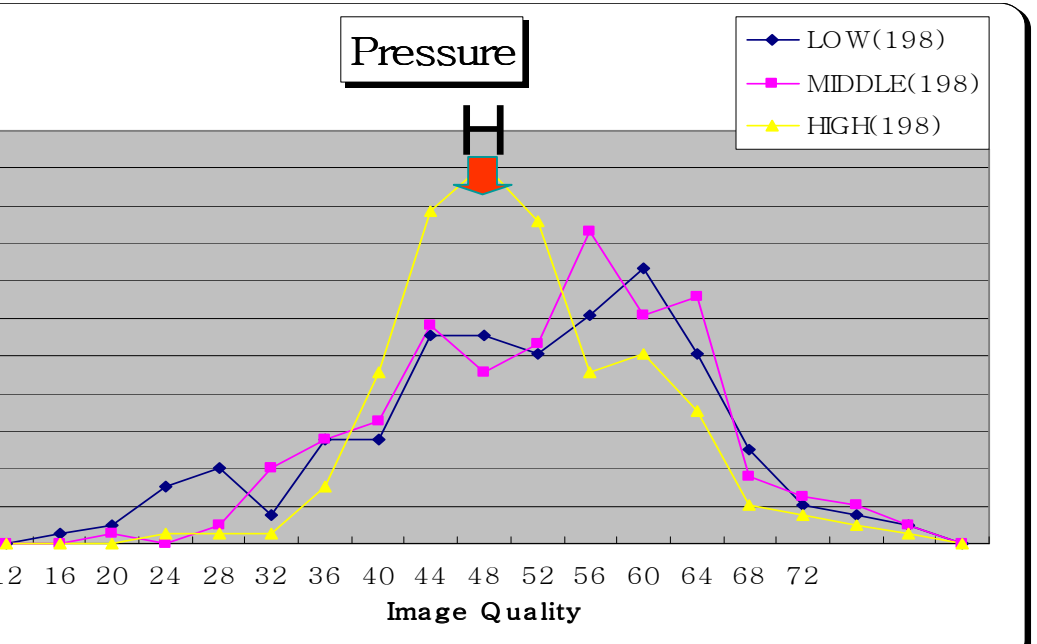


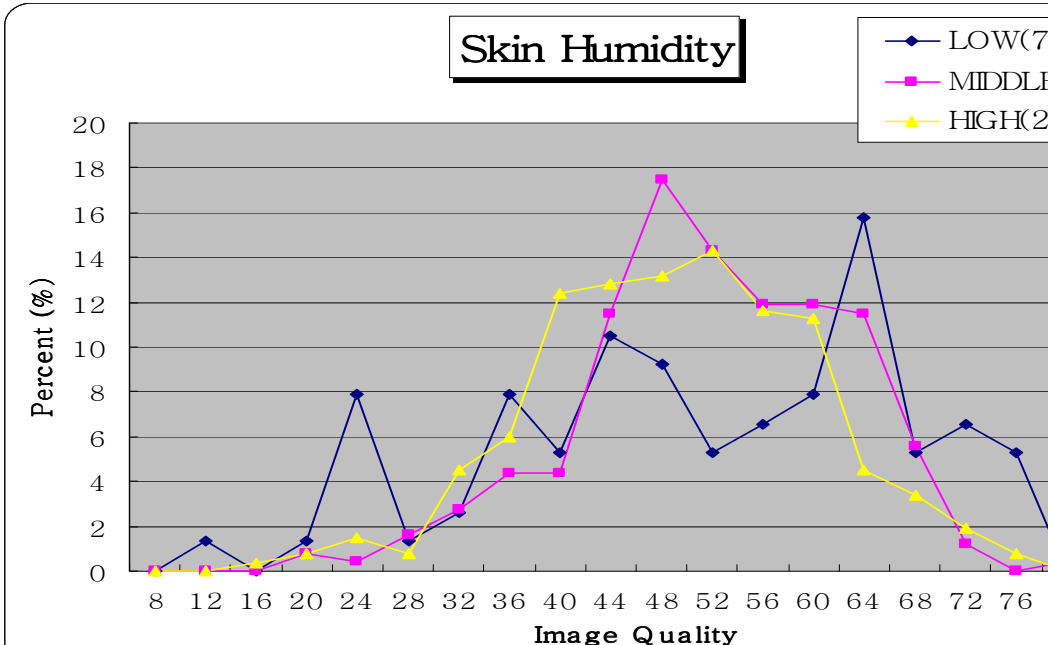


Influence on Thermal Sensor





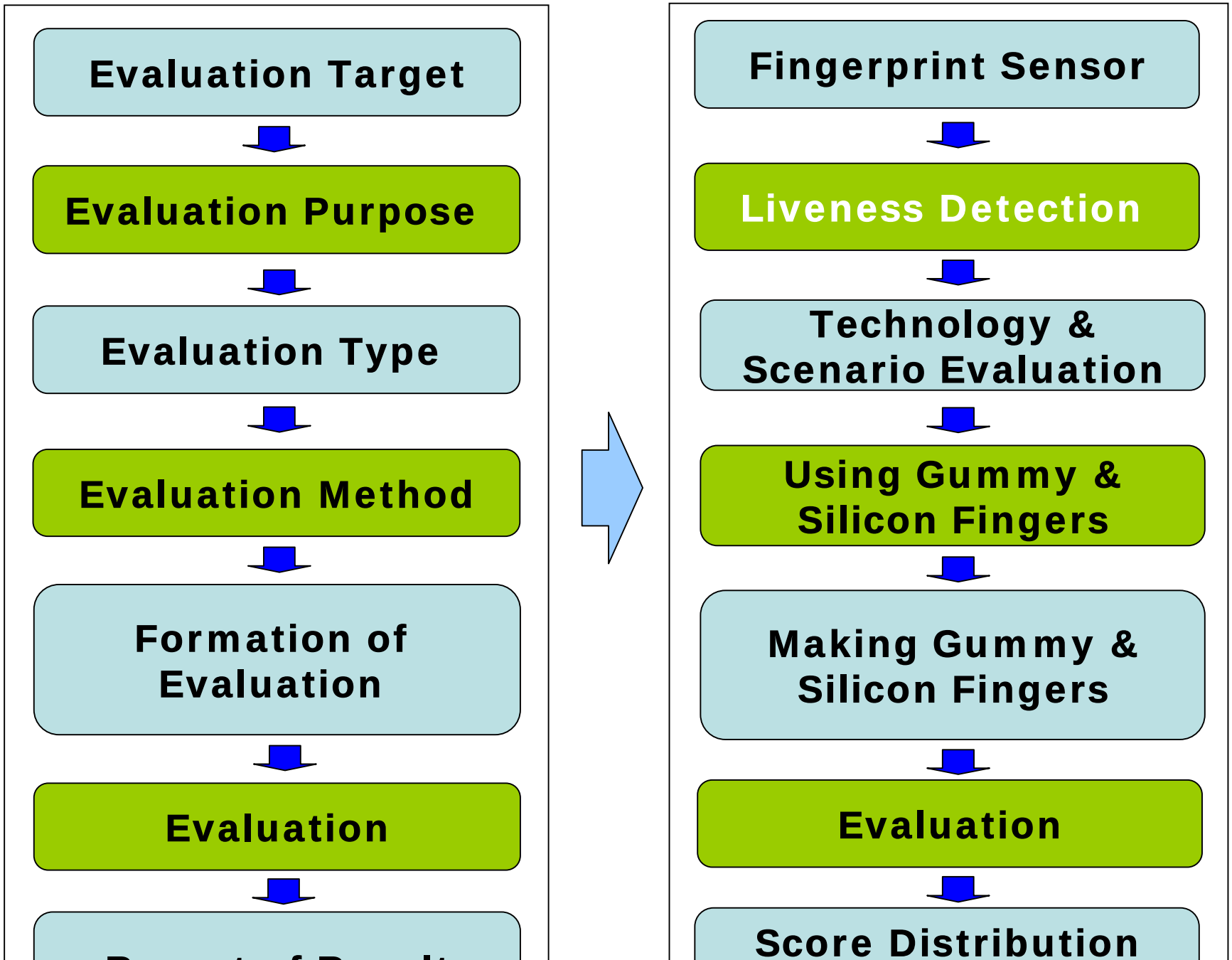




Observation I

Sensor Type	Environmental Factors	Human Factors
Optical	Quality decreases when then temperature goes below zero due to dryness of skin	Foreground image gets smaller for the low pressur Skin humidity affects most the image quality
emiconductor	No change according to temperature levels as well as humidity level	Good images not only with the middle pressure but al with the high pressure
Tactile	No change according to temperature levels as well as humidity level	Tactile gives better image the low pressure than at th high pressure Skin humidity affects most the image quality
Thermal	No change according to temperature levels as well as humidity level	Due to sweeping, therma sensor is less affected

Experiment II



Formation of Evaluation: Making artificial fingers






Putty : Provil Novo, Gelatin : Bake Plus

Sample Images

A Live

B Live

C Live

D Live

A Gummy

B Gummy

C Gummy

D Gummy

Evaluation Methods

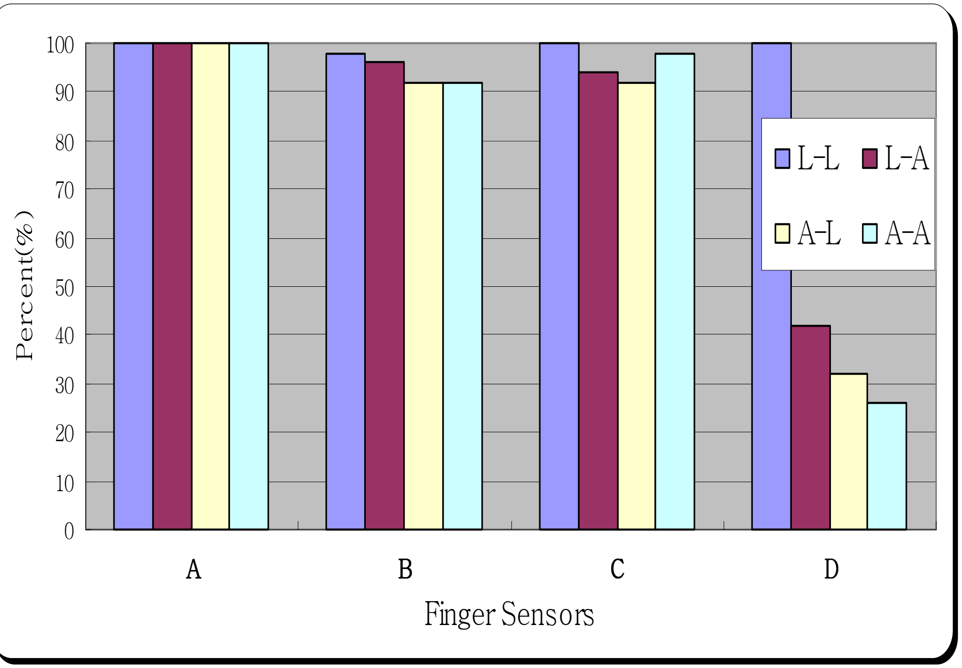
Types of Experiment

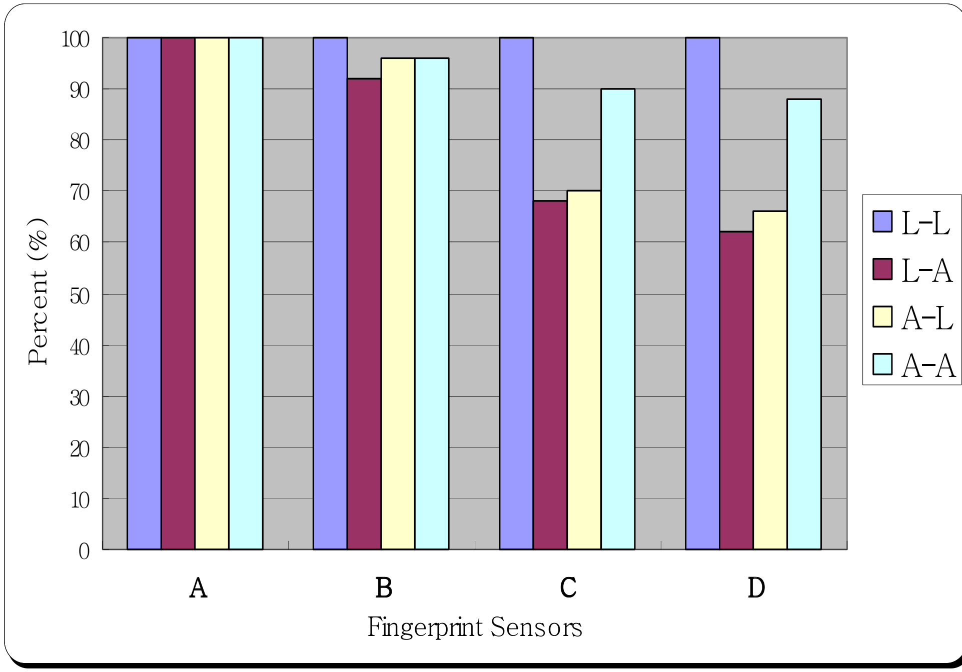
Type	Enrollment	Verification
L-L	Live Finger	Live Finger
L-A	Live Finger	Artificial Finger
A-L	Artificial Finger	Live Finger
A-A	Artificial Finger	Artificial Finger

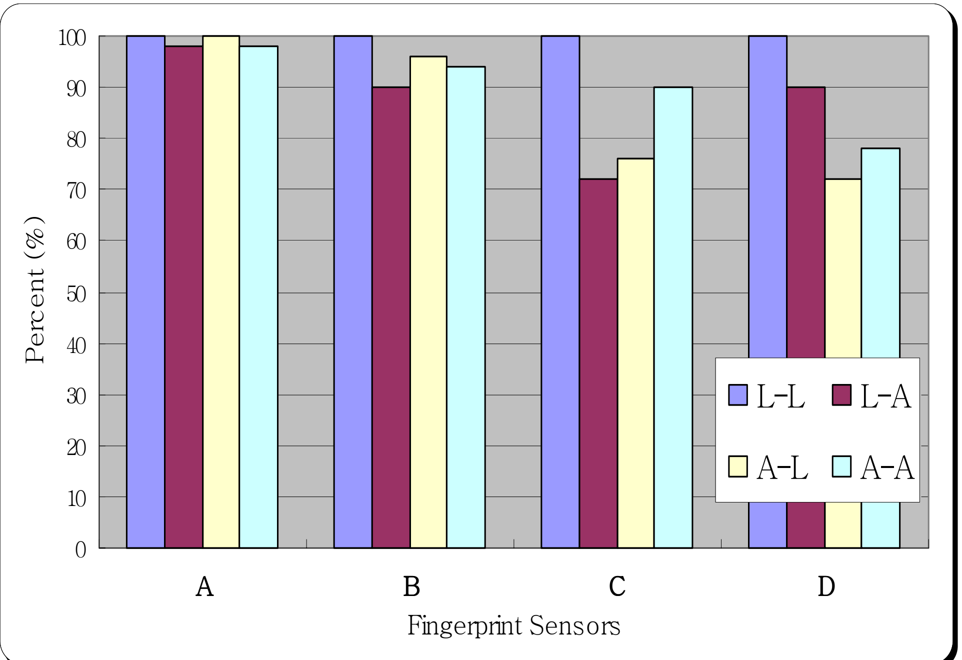
Evaluation

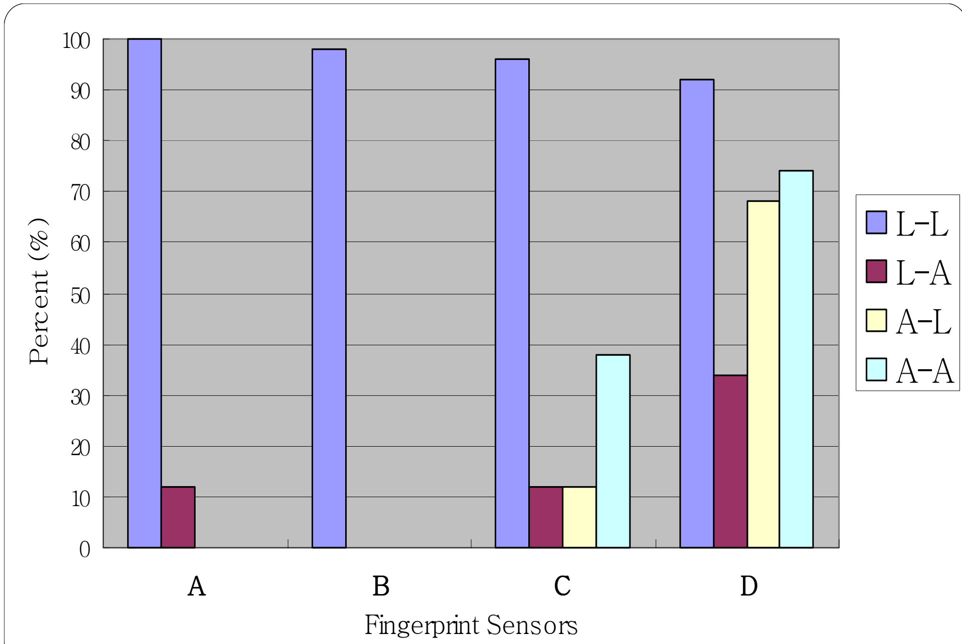
- Pass Rates in time-varying scenario tests
- Distribution of matching scores using a lab-made algorithm

Pass Rates of Gummy Finger

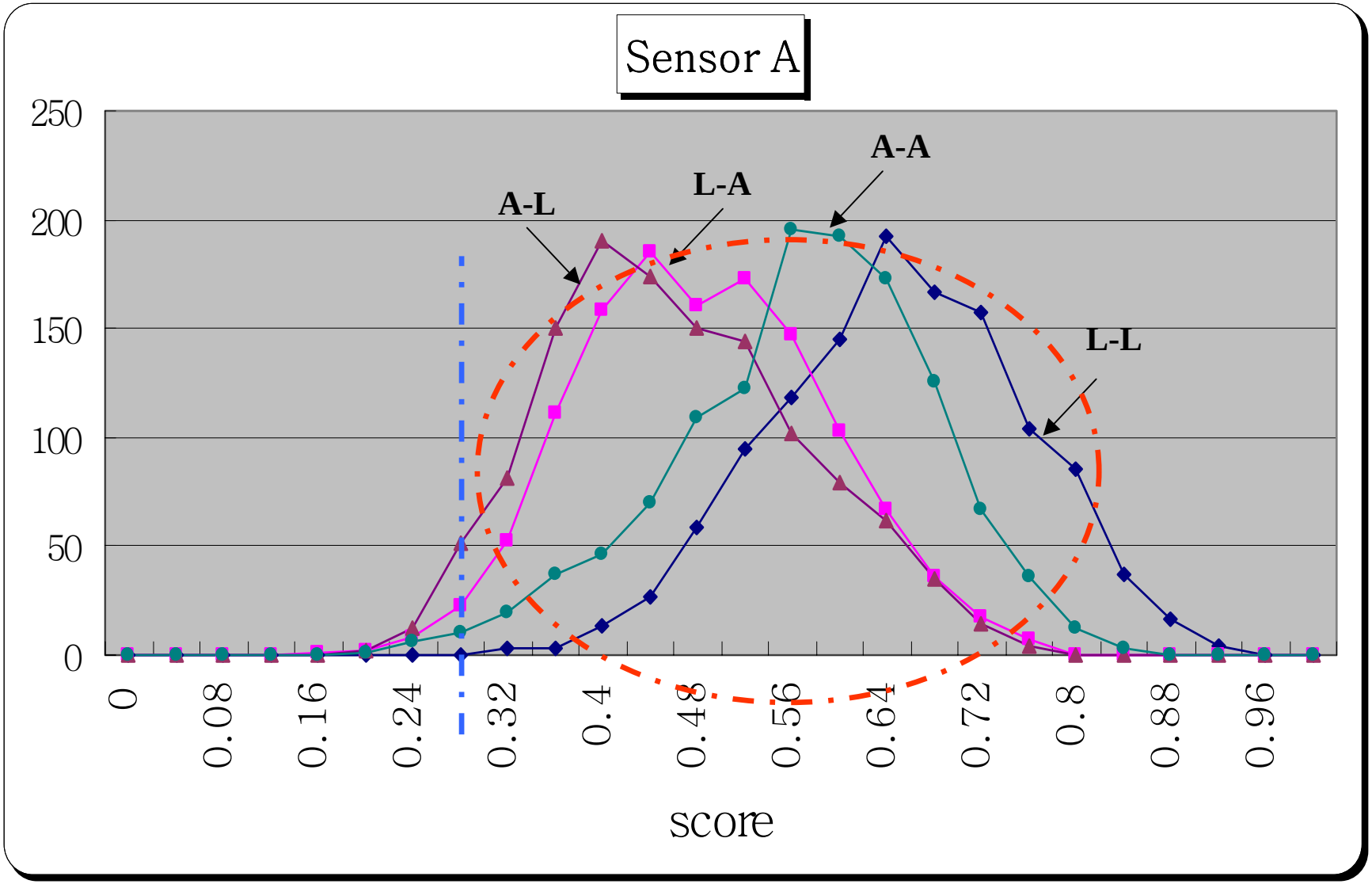




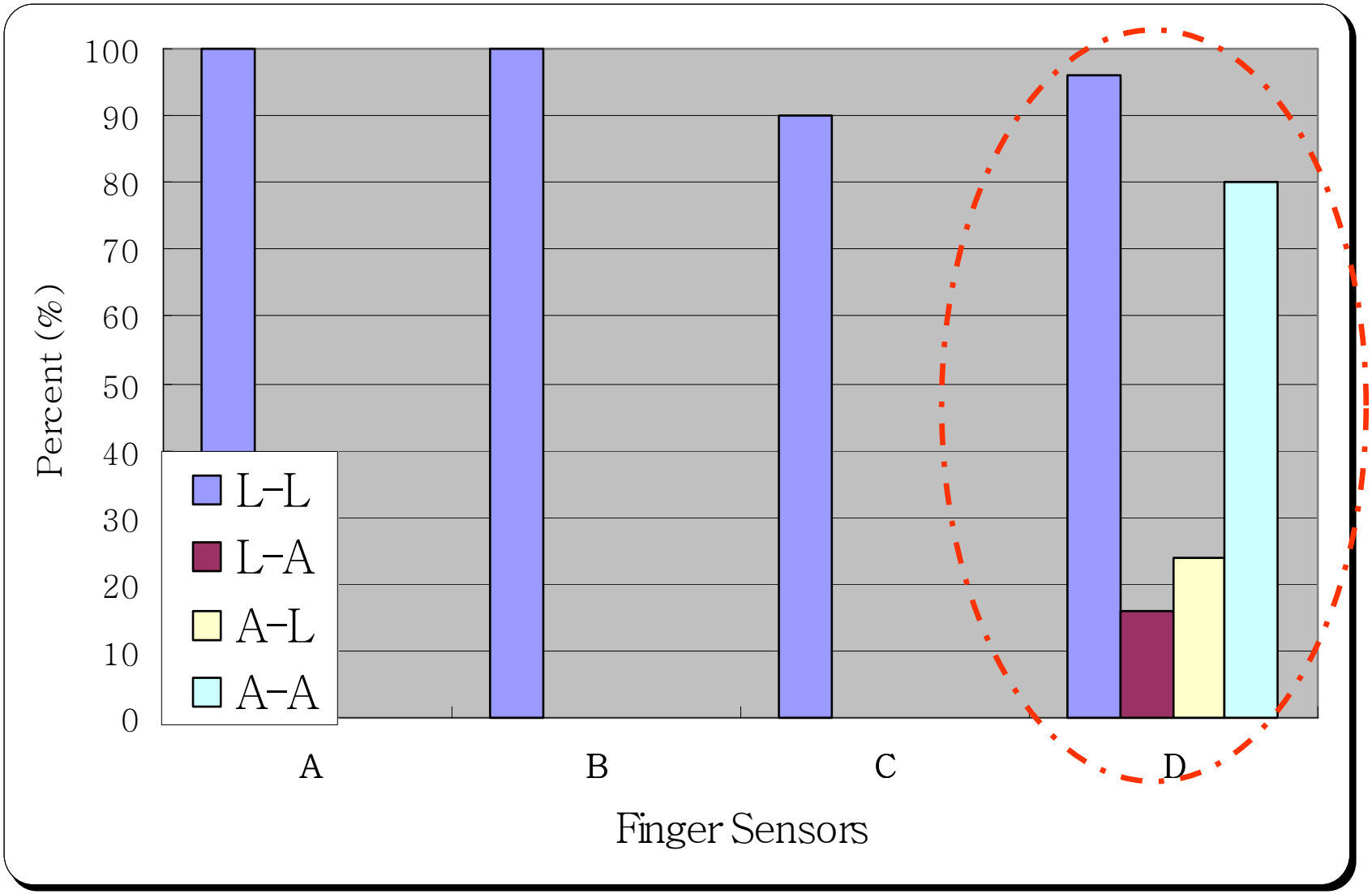




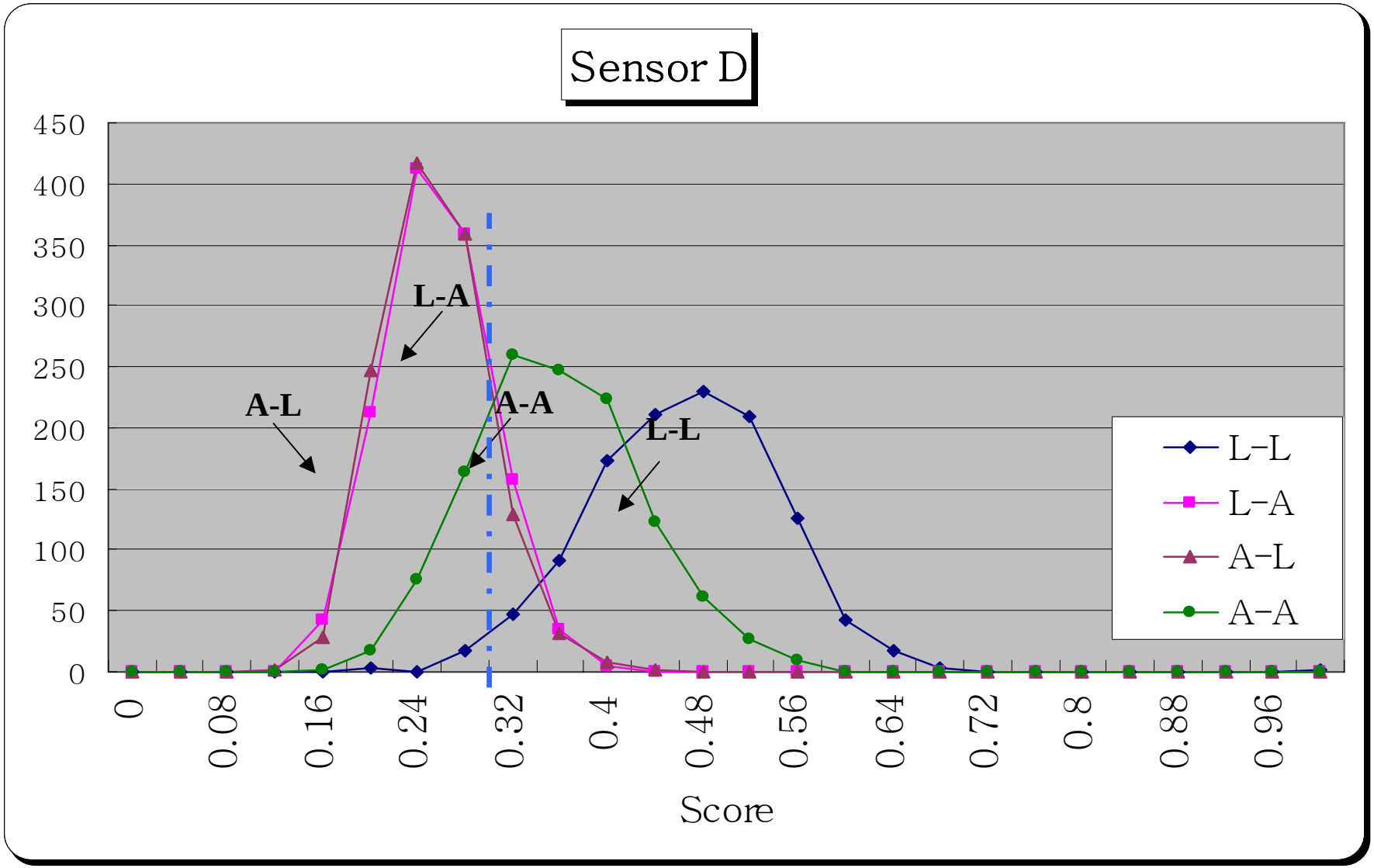
Score Distribution of Gummy Finger



Pass Rates of Silicon Rubber Finger



Score Distribution of Silicon Rubber Finger



Observation II

Sensor Type	Gummy Finger	Silicon Finger
Optical	Pass-rate decreases as time passes.	Optical sensor detects skin color.
emiconductor		Semiconductor sensor uses conductivity of liv body.
Tactile		Tactile sensor respons to conductive material.
Thermal	Pass-rate of Thermal sensor increases as time passes.	Thermal sensor can be spoofed with both silic rubber and gummy fingers.
All	All fingerprint readers accept the gummy finger in their verification procedures.	

Conclusion

Carried out evaluation and comparison of characteristic of various fingerprint readers in the aspects of liveness detection and influence of operating conditions on imag quality.

Demonstrated experimental procedures for performanc evaluation of fingerprint reader modules.

Experimental results can be utilized for improving or choosing fingerprint reader modules.