IFC-Bank of Italy Workshop on "Machine learning in central banking"

19-22 October 2021, Rome / virtual event

Using deep learning technique to automate banknote defect classification[1]

Jiradett Kerdsri and Pucktada Treeratpituk,
Bank of Thailand

[1] This presentation was prepared for the Workshop. The views expressed are those of the authors and do not necessarily reflect the views of the Bank of Italy, the BIS, the IFC or the central banks and other institutions represented at the event.

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Using Deep Learning Technique to Automate Banknote Defect Classification

Jiradett Kerdsri, Pucktada Treeratpituk

Department of Data Management and Data Analytics
Bank of Thailand

20 October 2021

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Motivation

To increase the efficiency of our banknote printing operation

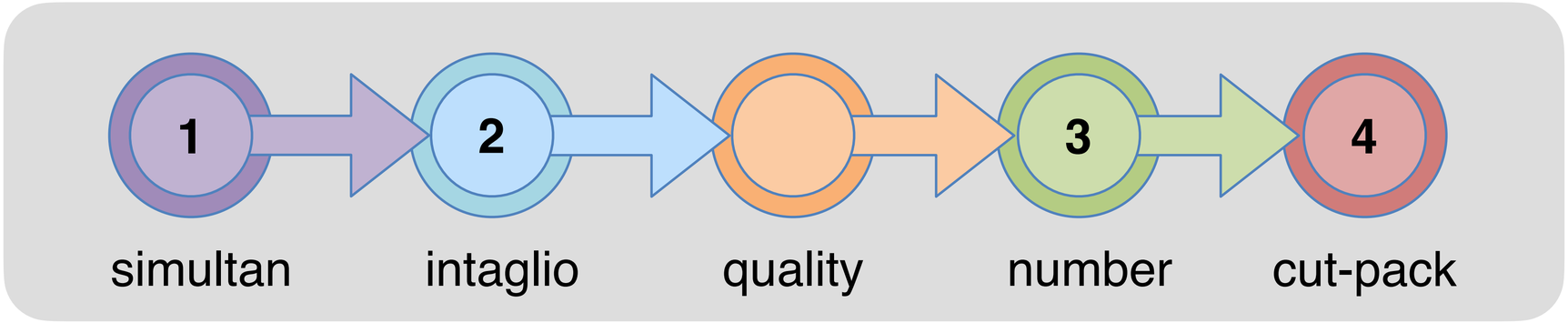
- By reducing defect rate with real-time banknote printing quality inspection
- By reducing human effort involved in the inspection process

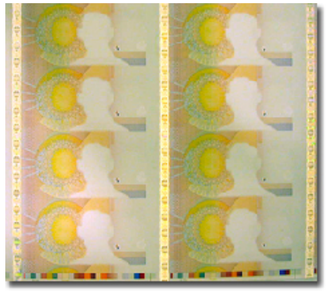
To expand ML applications into central bank operations (BAU) especially for more automation & lean processes

- *Statistical compilations, e.g. government spending, entity-resolution/disambiguation*
- *Human Resources*
- *Communications*
- ***Banknote printing works***

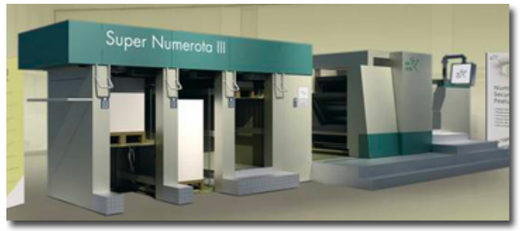
ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Banknote Printing Process

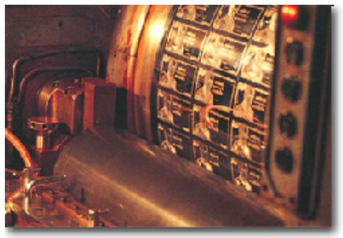




offset printing machine



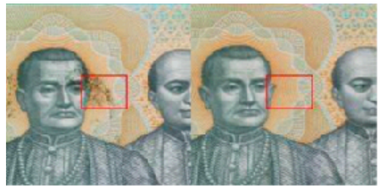
number printing machine



intaglio machine

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

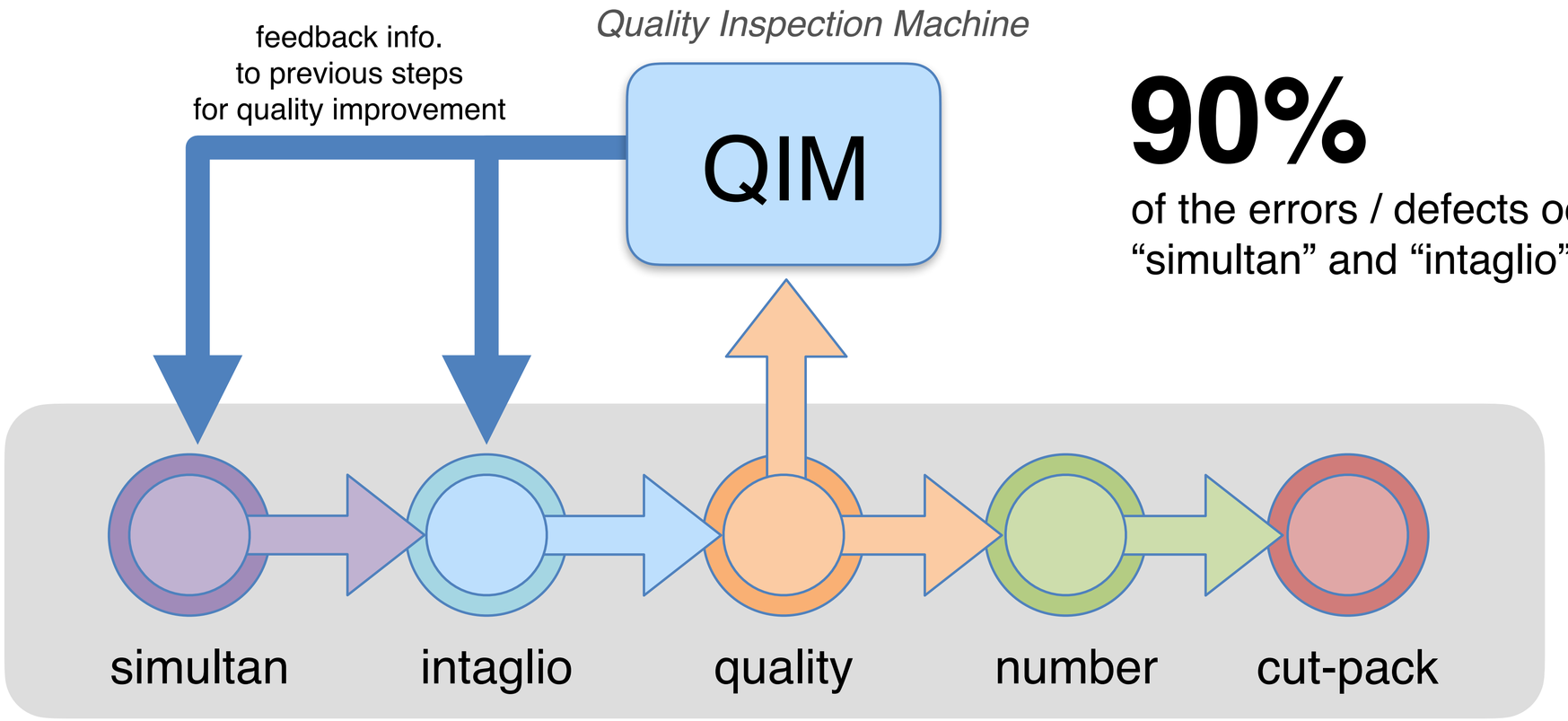
Quality Inspection



number of defects from the note printing process contributes to the cost of cash

1%
defect target

0.95%
~ actual defect percentage

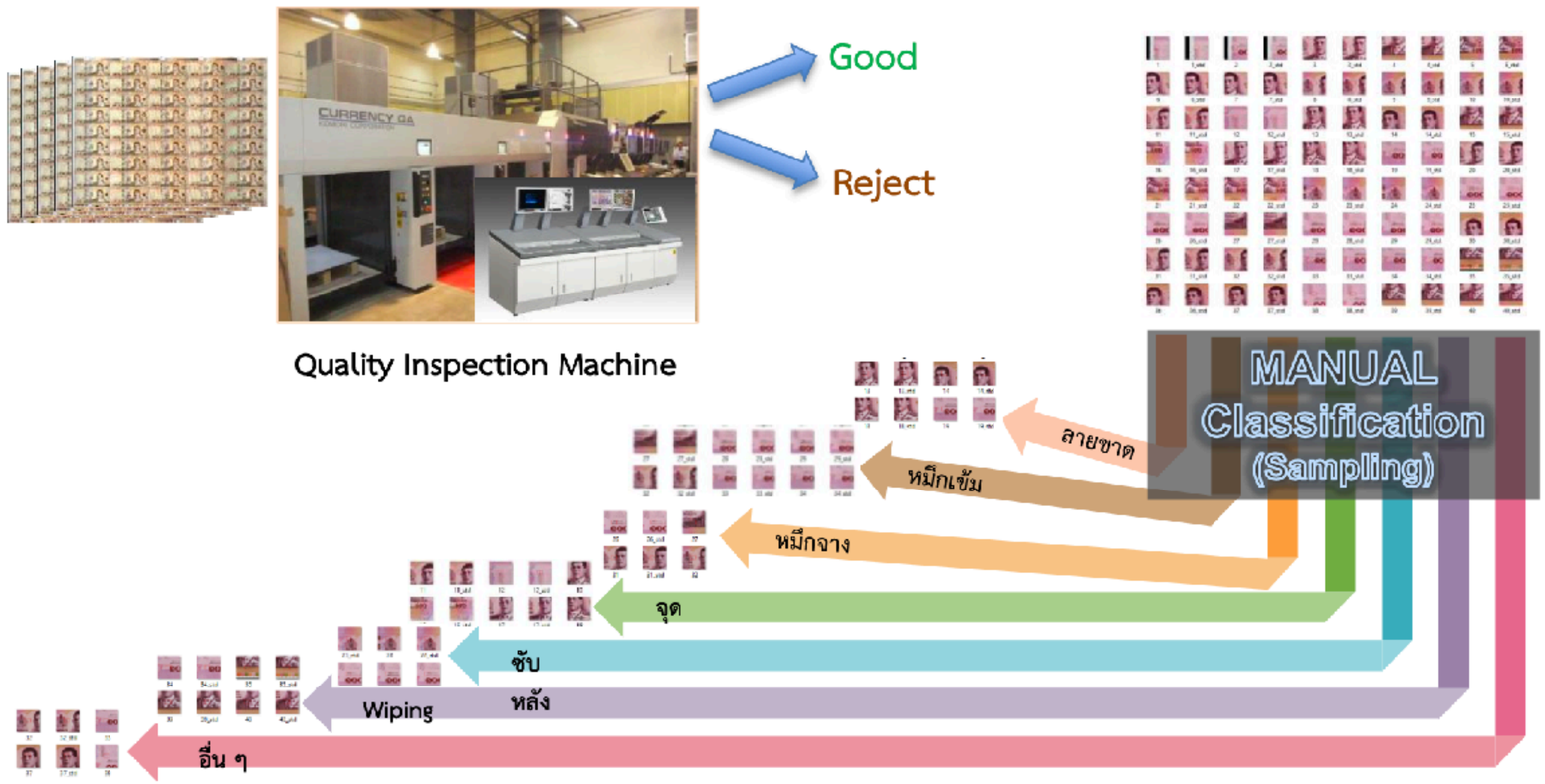


90%

of the errors / defects occurs in the “simultan” and “intaglio” steps

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Previous Process

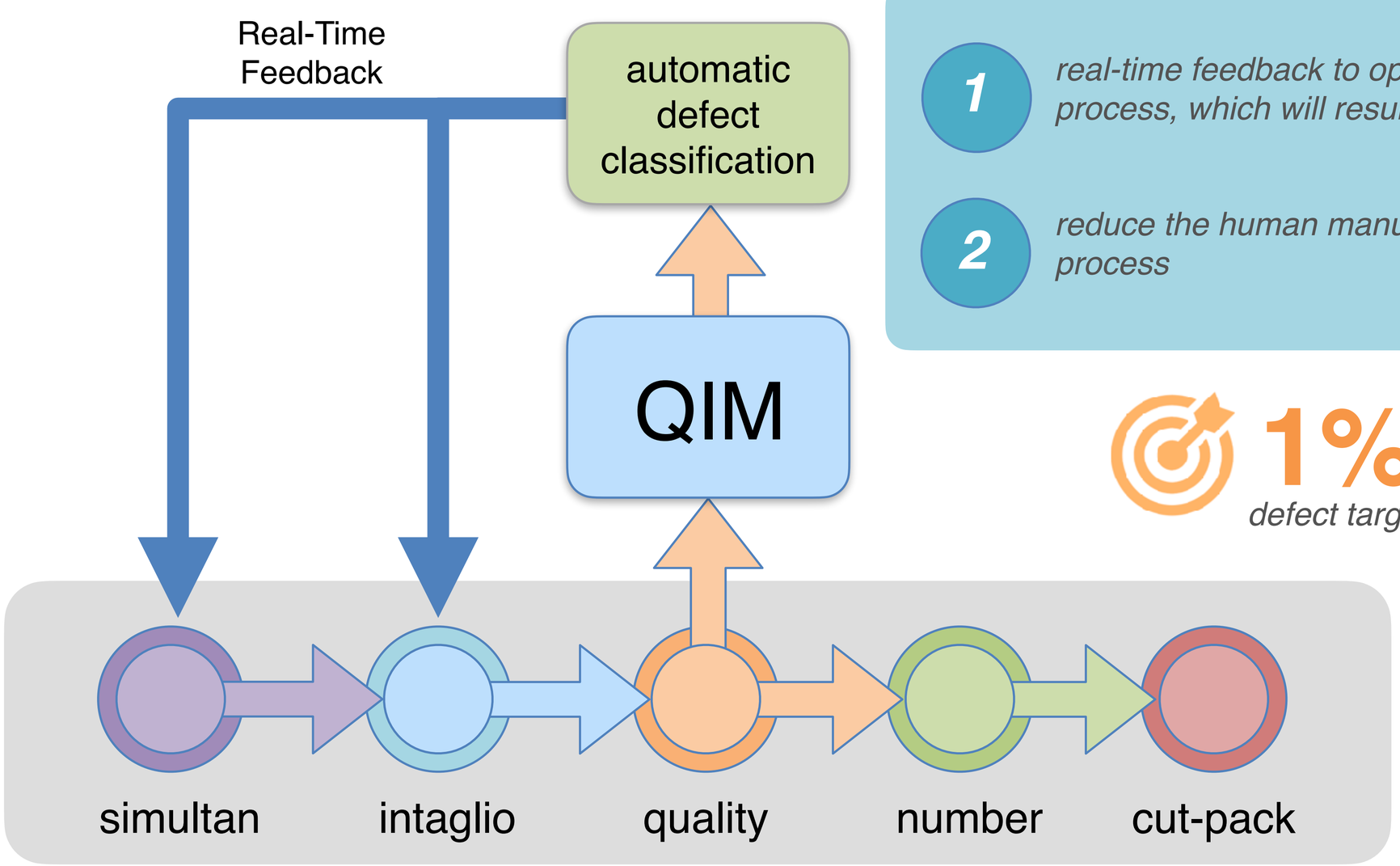


1. *require human inspector to manually classify and collect statistics of defect types to inform operators in previous steps*

2. *Inspections are carried out at the end-of-day, thus there are gaps between when the problems was found and when the adjustment will be made*

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Automatic Defect Classification



1. *real-time feedback to operators of the printing process, which will result in faster fixes*
2. *reduce the human manual work-load in the process*

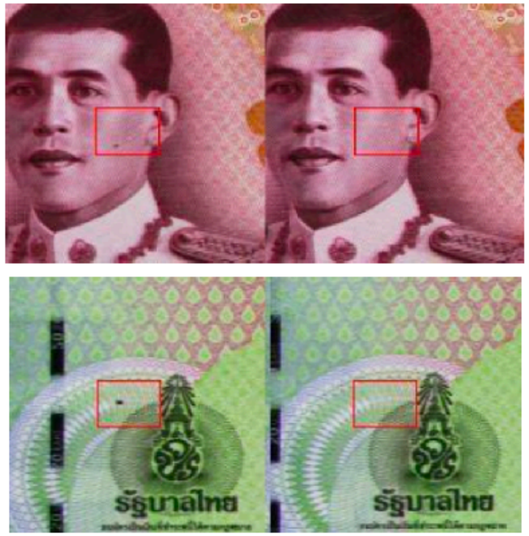
1%
defect target

20%
reduction of defect

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

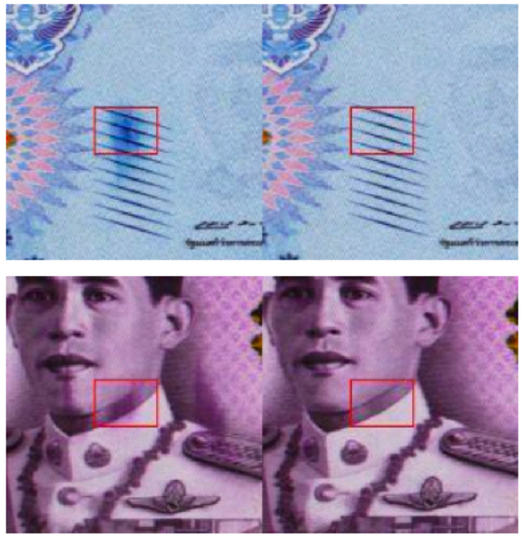
Examples: Banknote Defects

Dot/Ink Spot



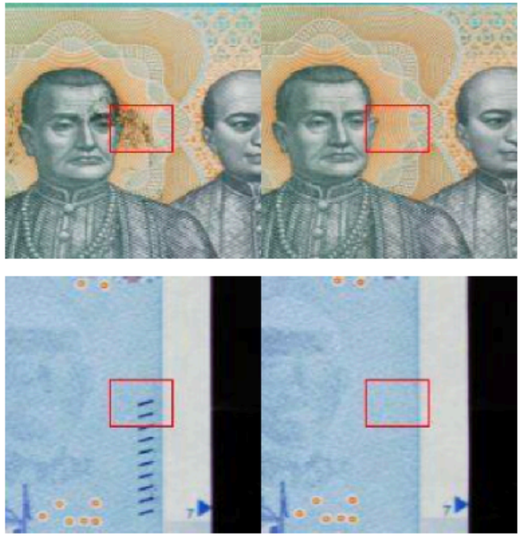
Defect *Normal*

Wiping



Defect *Normal*

Set-Off



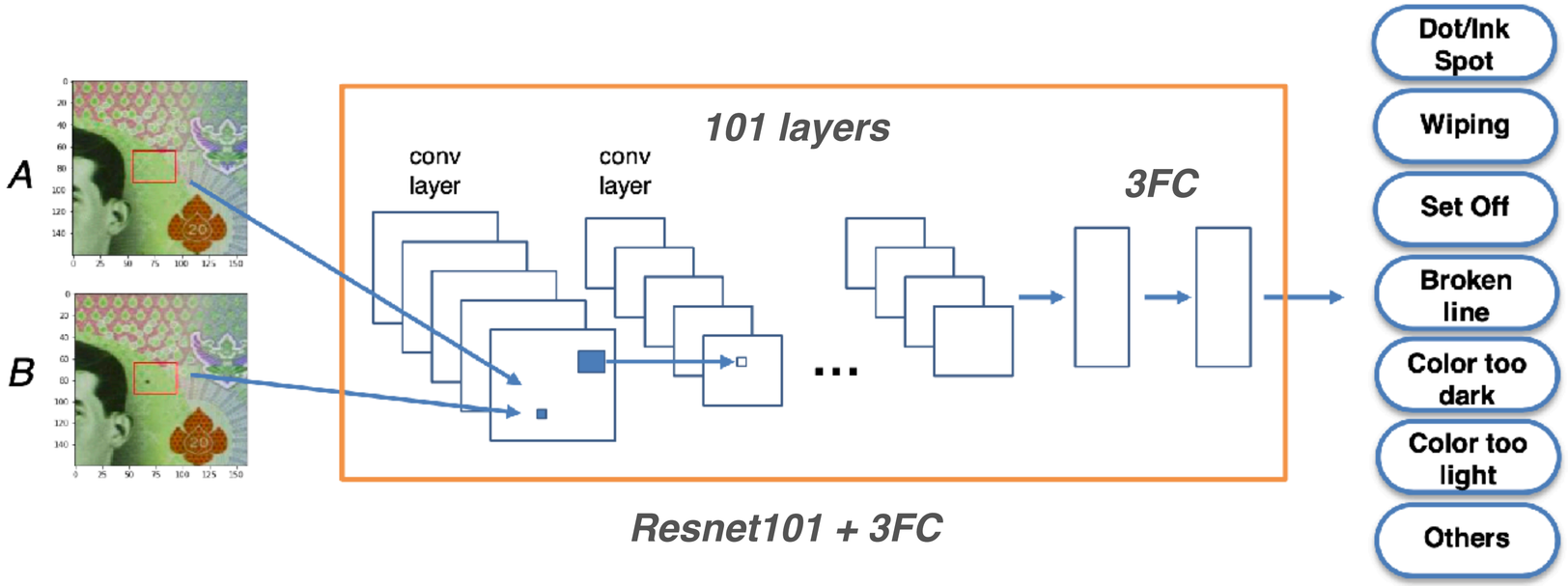
Defect *Normal*

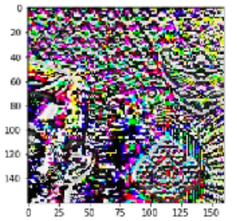
ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Methodology
Automatic Defect Classification

***Model**: ResNet-101* + 3FC*
[one shared model for 5 banknote denominations]

***Input**: image pair (defect banknote + standard banknote)*
***Output**: 7 defect classes*





A - B

photos are not properly aligned, so simply subtract two images won't work

** K. He, X. Zhang, S. Ren, and J. Sun, Deep Residual Learning for Image Recognition, CVPR, 2016*

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Accuracy

Training (1,659 banknote defects)

97% **Test Accuracy** *(Out-Of-Sample)*

Operational

74% **Accuracy** *Operational*

	Dot (Front)			Dot (Back)			Wiping (Front)			Set Off (Back)		
	Model	*Manual*	*Acc*	*Model*	*Manual*	*Acc*	*Model*	*Manual*	*Acc*	*Model*	*Manual*	*Acc*
20 Baht	467	461	99%	366	330	90%	1066	1023	96%	327	306	94%
50 Baht	438	392	89%	184	102	55%	1416	692	49%	252	186	74%
100 Baht	947	946	100%	231	229	99%	575	543	94%	612	564	92%
500 Baht	247	229	93%	184	145	79%	1319	177	13%	627	525	84%
1000 Baht	123	123	100%	59	54	92%	433	163	38%	654	592	91%
Sum	2222	2151	97%	1024	860	84%	4809	2598	54%	2472	2173	88%

ธนาคารแห่งประเทศไทย
BANK OF THAILAND

Future Work

Improving performance on all 7 types of defects (90% coverage), currently work best only on the 3 biggest defect types

- Increase accuracy to 90%+, via more training data
- Expanding to front & bank variations (certain error types occur mostly only on one side)

Expanding to the automatic quality inspection to the cut-pack step