Real-Time Architecture Laboratory

Kwangwoon University

2021. 1. 20

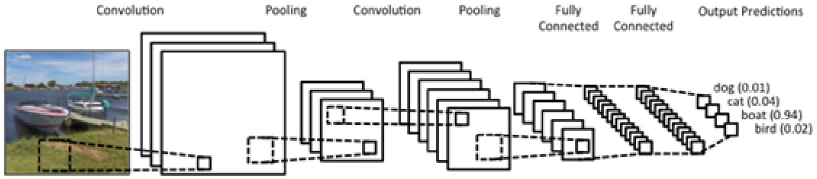
Prof. Yong-Jin Jeong

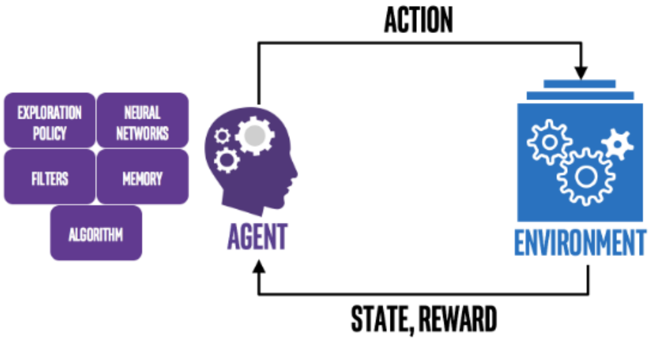
Introduction

The Real-Time Architecture Laboratory (RTA) in Kwangwoon University under Professor Yong-Jin Jeong started on semiconductor chip design and embedded design for real-time performance of algorithms used in security, computer arithmetic, and image processing.

Now, Research Expanded to:

1. Applications for Surveillance and Security
   - New Algorithms for Computer Vision
   - Deep Learning Applications
   - New Algorithm for Hardware security
2. Management and Finance using AI
   - Machine Learning based methodology
3. Reinforcement Learning
   - Reinforcement Learning Applications
   - RL and Blockchain Convergence

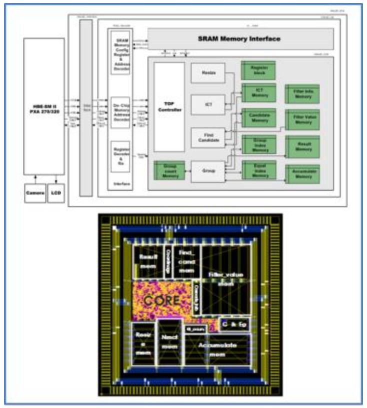

Convolution
Pooling
Convolution
Pooling
Fully Connected
Fully Connected
Output Predictions
dog (0.01)
cat (0.04)
boat (0.94)
bird (0.02)


ACTION
EXPLORATION POLICY
NEURAL NETWORKS
FILTERS
MEMORY
ALGORITHM
AGENT
ENVIRONMENT
STATE, REWARD

Previous Works on SoC and FPGA Implementations

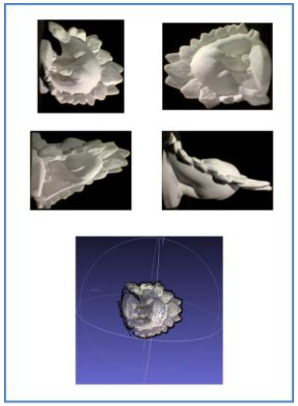
Face Detection

< Face Detection Demo >

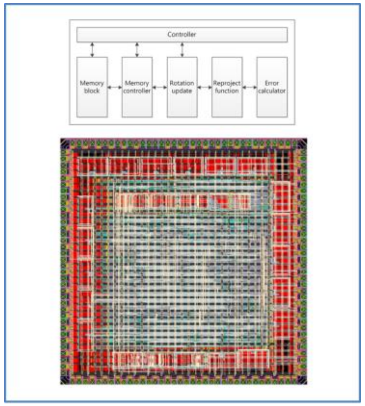

SRAM Memory Interface
HBE-SM II PXA 270/320
Camera
LCD
SRAM Memory Config Register & Address Decoder
On-Chip Memory Address Decoder
Register Decoder & Rx
Interface
TOP Controller
Resize
ICT
Find Candidate
Group
Register block
ICT Memory
Candidate Memory
Group Index Memory
Equal Index Memory
Group count Memory
Filter Info Memory
Filter Value Memory
Result Memory
Accumulator Memory
Result mem
find_cand mem
Filter_value mem
CORE
Resize mem
Nmcl mem
Accumulate mem

< H/W Architecture & MPW Layout >

3D Reconstruction

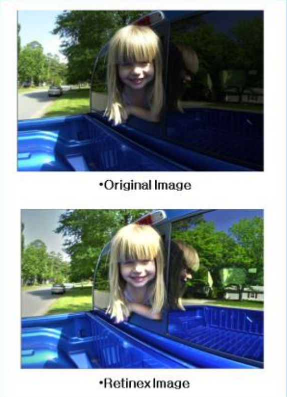


< 3D reconstruction Demo >


Controller
Memory block
Memory controller
Rotation update
Reproject function
Error calculator

< H/W Architecture & MPW Layout >

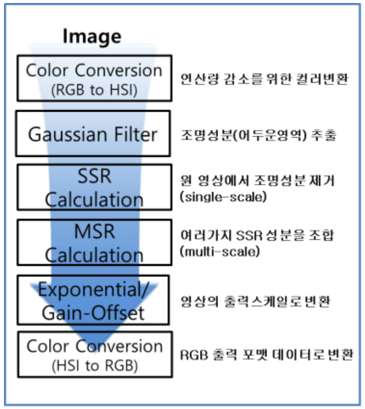
Retinex Image Enhancement



•Original Image

•Retinex Image

< Image Enhancement-Retinex>

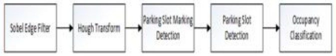


Image

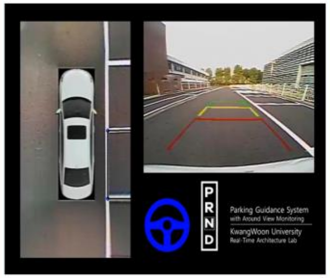
Color Conversion (RGB to HSI)	연산량 감소를 위한 컬러변환
Gaussian Filter	조명성분(어두운영역) 추출
SSR Calculation	원 영상에서 조명성분 제거 (single-scale)
MSR Calculation	여러가지 SSR 성분을 조합 (multi-scale)
Exponential/ Gain-Offset	영상의 출력스케일로 변환
Color Conversion (HSI to RGB)	RGB 출력 포맷 데이터로 변환

< S/W Algorithm Flow>

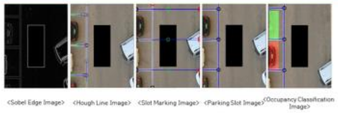
Parking Guidance System


Sobel Edge Filter
Hough Transform
Parking Slot Marking Detection
Parking Slot Detection
Occupancy Classification

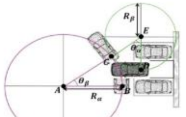
< S/W Algorithm Flow>


P
R
N
D
Parking Guidance System
with Around View Monitoring
KwangWoon University
Real-Time Architecture Lab

< PGS DEMO >



<Sobel Edge Image> <Hough Line Image> <Slot Marking Image> <Parking Slot Image> <Occupancy Classification Image>


R_β
E
θ_α
G
θ_β
A
B
R_α

< Path Planning Model >

- 주차선 검출을 통한 주차공간 인식
- 주차공간 내의 장애물 확인
- 매 프레임마다 차량의 주차 경로 계산 및 가이드
- 차량의 이탈 유무 판단 및 PC환경에서 AVM 이미지를 이용한 시뮬레이션 환경 구성

1

Applications for Surveillance and Security

- Presents Researches for Different Applications in Security and Surveillance

1.1 License Plate Recognition

Formal Published Paper Title: Development of License Plate Recognition on Complex Scene with Plate-Style Classification and Confidence Scoring Based on KNN, 2018

- Features a 3-stage algorithm for detection, extraction, and recognition of license plates from complex scenes

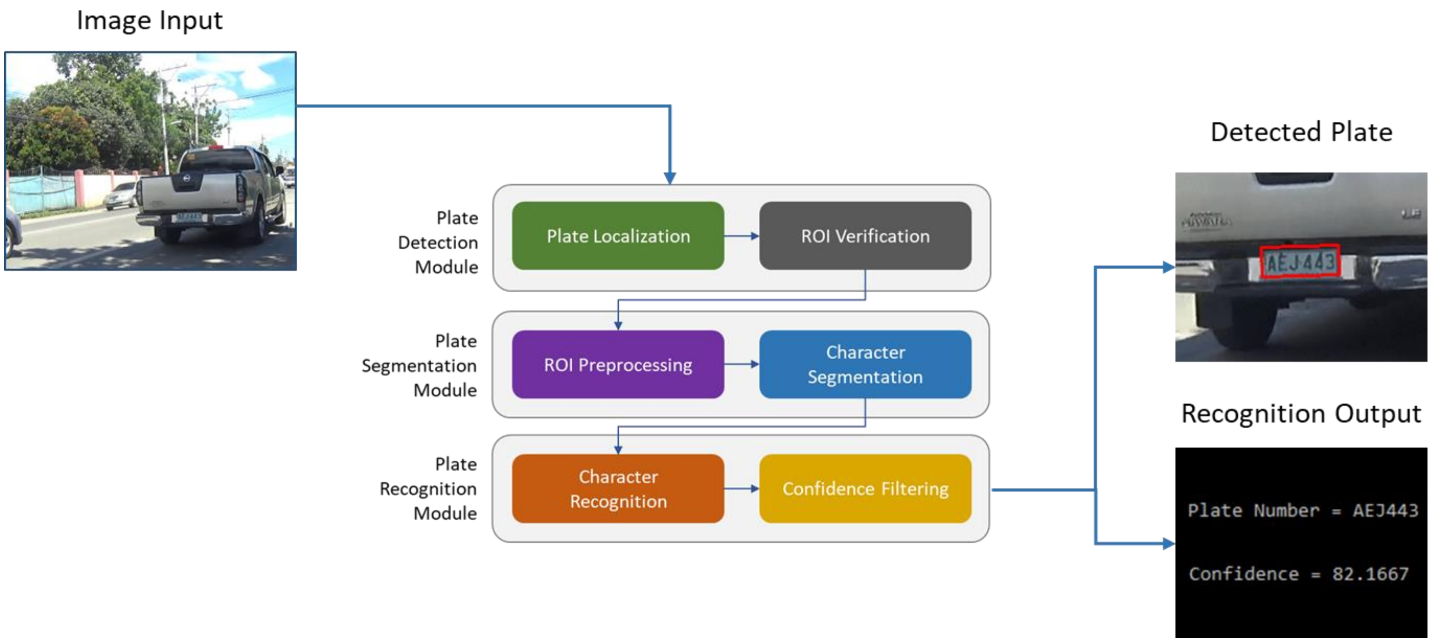


Image Input

Plate Detection Module: Plate Localization → ROI Verification

Plate Segmentation Module: ROI Preprocessing → Character Segmentation

Plate Recognition Module: Character Recognition → Confidence Filtering

Detected Plate

Recognition Output

```
Plate Number = AEJ443

Confidence = 82.1667
```

1.2 Background Subtraction

Formal Published Paper Title: Fast Background Subtraction with Adaptive Block Learning Using Expectation Value Suitable for Real-time Moving Object Detection, 2021

- Algorithm for detecting the foreground (detect moving objects)
- Very fast (real-time) execution speed with well-rounded performance

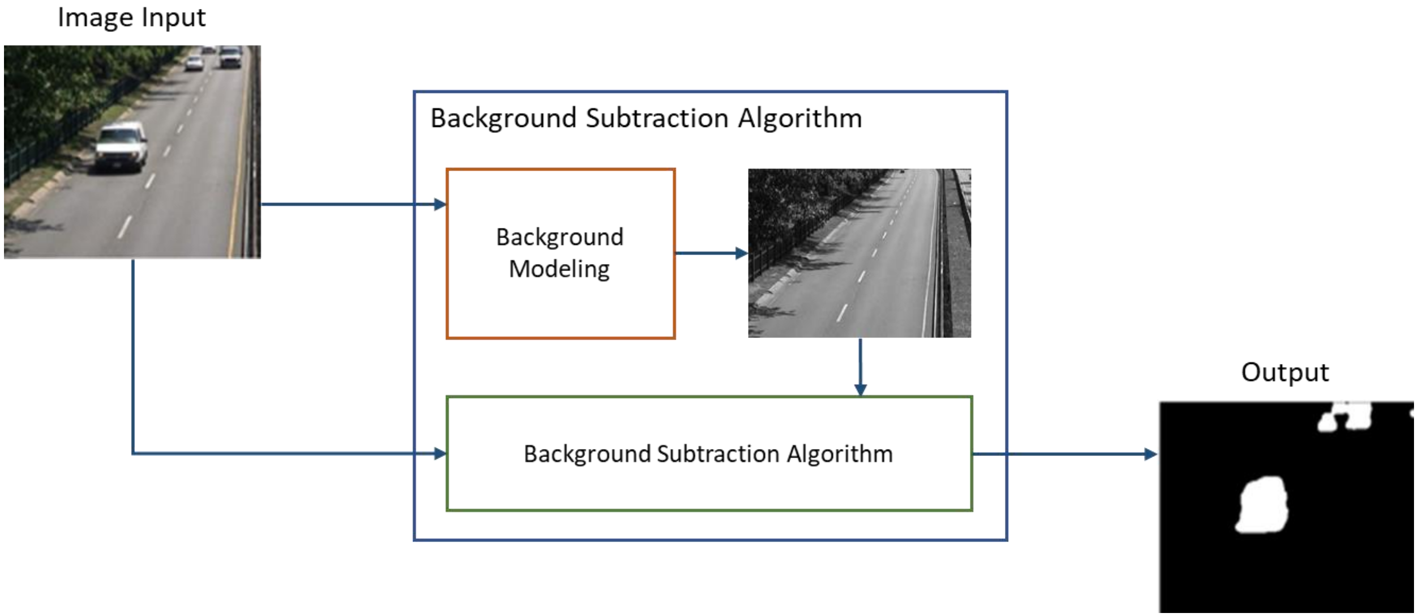


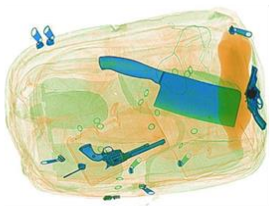
Image Input
Background Subtraction Algorithm
Background Modeling
Background Subtraction Algorithm
Output

1.3 X-Ray Security Anomaly Detection

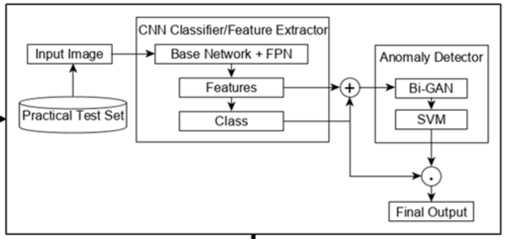
Formal Published Paper Title: A New GAN-Based Anomaly Detection (GBAD) approach for Multi-Threat Object Classification on Large-Scale X-Ray Security Images, 2020

- Training method for large-scale X-ray dataset (extremely imbalanced)
- A new three-stage training scheme designed to mitigate the effect of extreme class imbalance

X-ray Image Input



Three-stage GAN-based classifier


Input Image
Practical Test Set
CNN Classifier/Feature Extractor
Base Network + FPN
Features
Class
+
Anomaly Detector
Bi-GAN
SVM
·
Final Output

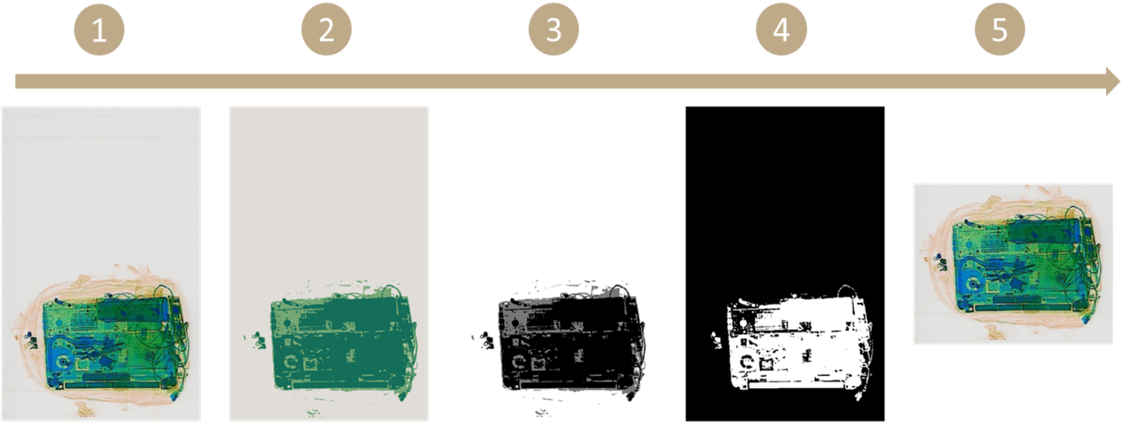
Threat Detection Output

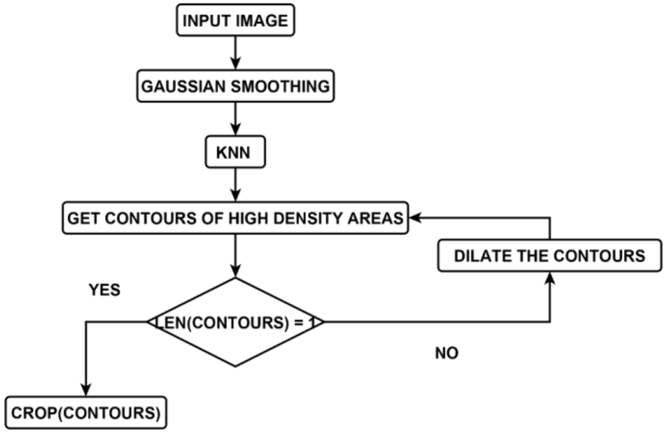
Threat	Detected
Gun	Yes
Knife	Yes
Wrench	No
Pliers	No
Scissors	No

1.4 Cropping Method for X-Ray Security Dataset

Formal Published Paper Title: KNN-Based Automatic Cropping for Improved Threat Object Recognition in X-Ray Security Images, 2019

- Presents a cropping method for X-ray security images to crop-out unimportant areas
- Improves training results by using images that only contains important areas




INPUT IMAGE

GAUSSIAN SMOOTHING

KNN

GET CONTOURS OF HIGH DENSITY AREAS

DILATE THE CONTOURS

LEN(CONTOURS) = 1

YES

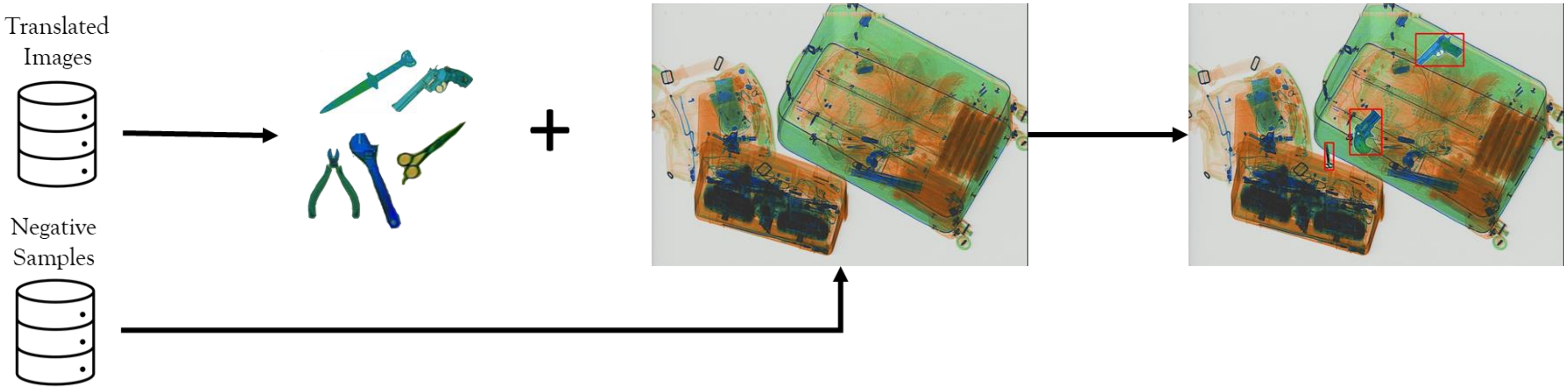
NO

CROP(CONTOURS)

1.5 GAN-based Image Augmentation

Formal Published Paper Title: Evaluating GAN-Based Image Augmentation for Threat Detection in Large-Scale Xray Security Images, 2021

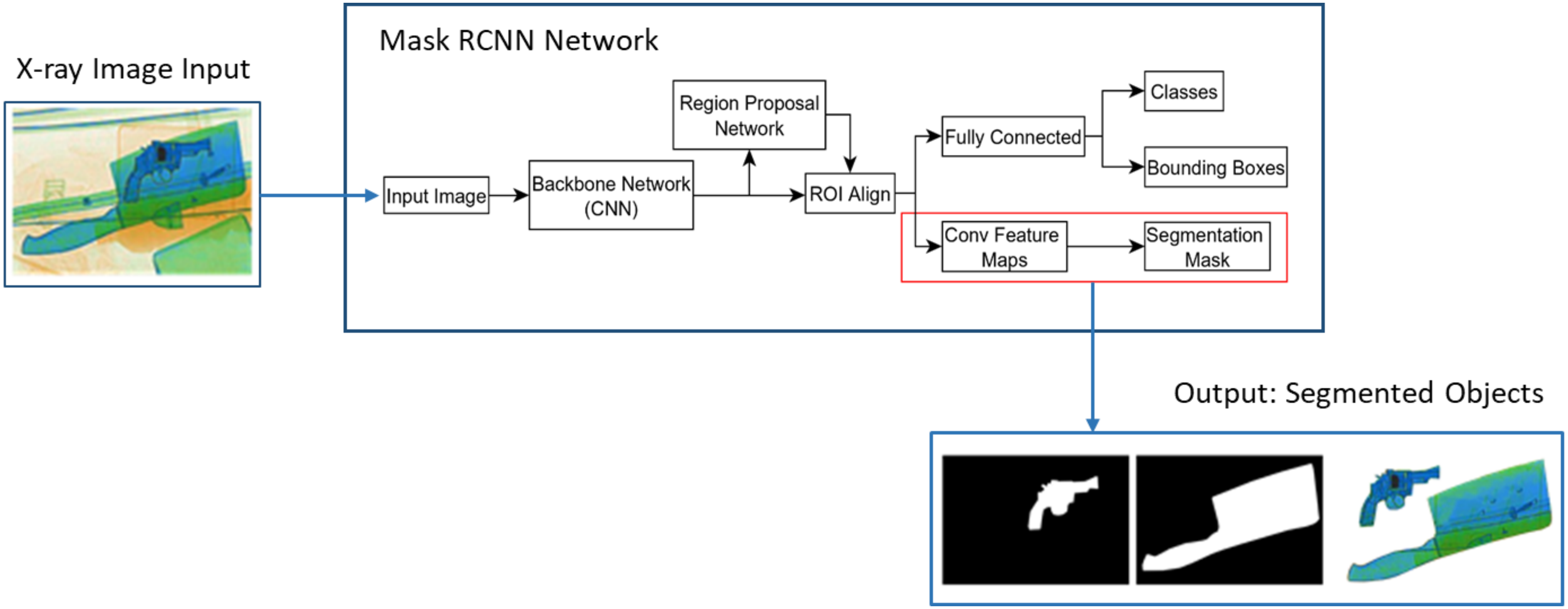
- Uses image augmentation (transformation, generation and translation) to address the class imbalance in a practical x-ray dataset
- Combines image synthesis and image augmentation approaches to enlarge the x-ray security image dataset.



1.6 Object Separation in X-ray Security Images

Formal Research Title: Deep Learning-Based Approach to Object Separation in Single-View X-ray Security Images

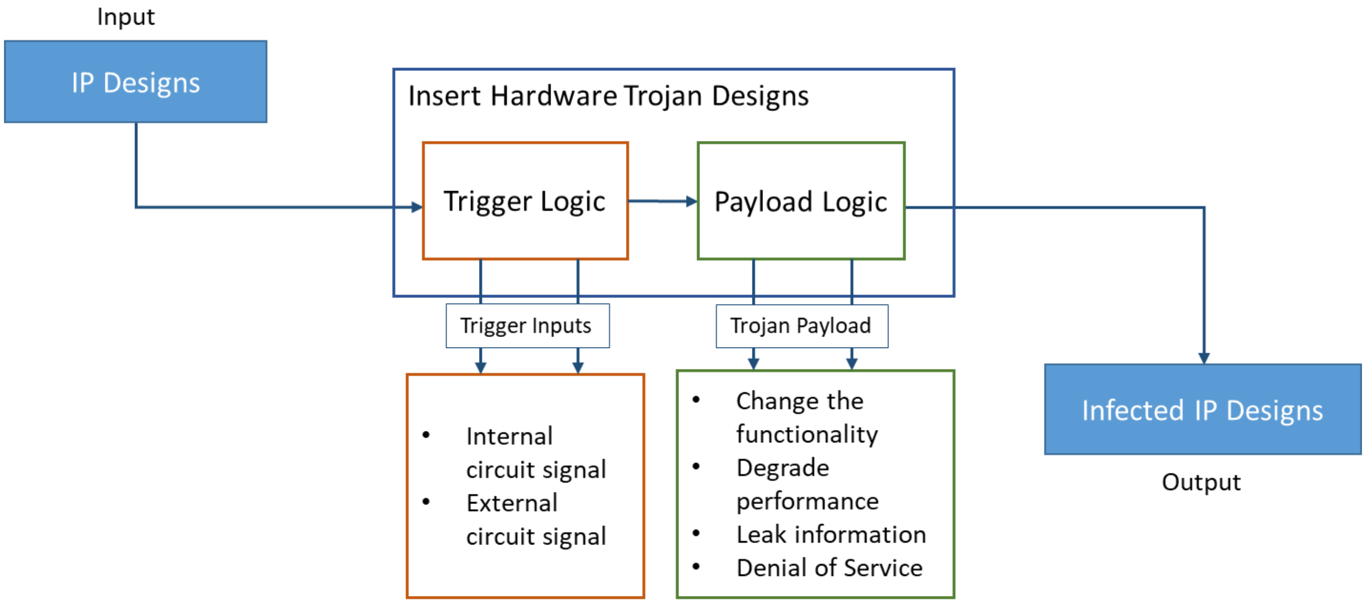
- Deep learning approach for object separation in X-ray images with overlapping objects


X-ray Image Input
Mask RCNN Network
Input Image
Backbone Network (CNN)
Region Proposal Network
ROI Align
Fully Connected
Classes
Bounding Boxes
Conv Feature Maps
Segmentation Mask
Output: Segmented Objects

1.7 Hardware Security

Formal Published Paper Title: Employing Linear Feedback Shift Register as a New Hardware Trojan and Extending ML-FASTrust Method as its Detection Algorithm

- Designed to evade existing state-of-the-art detection for existing hardware Trojans
- Extended hardware Trojan detection method to attain possible defense



Input

IP Designs

Insert Hardware Trojan Designs

Trigger Logic

Payload Logic

Trigger Inputs

Trojan Payload

- Internal circuit signal
- External circuit signal

- Change the functionality
- Degrade performance
- Leak information
- Denial of Service

Infected IP Designs

Output

2

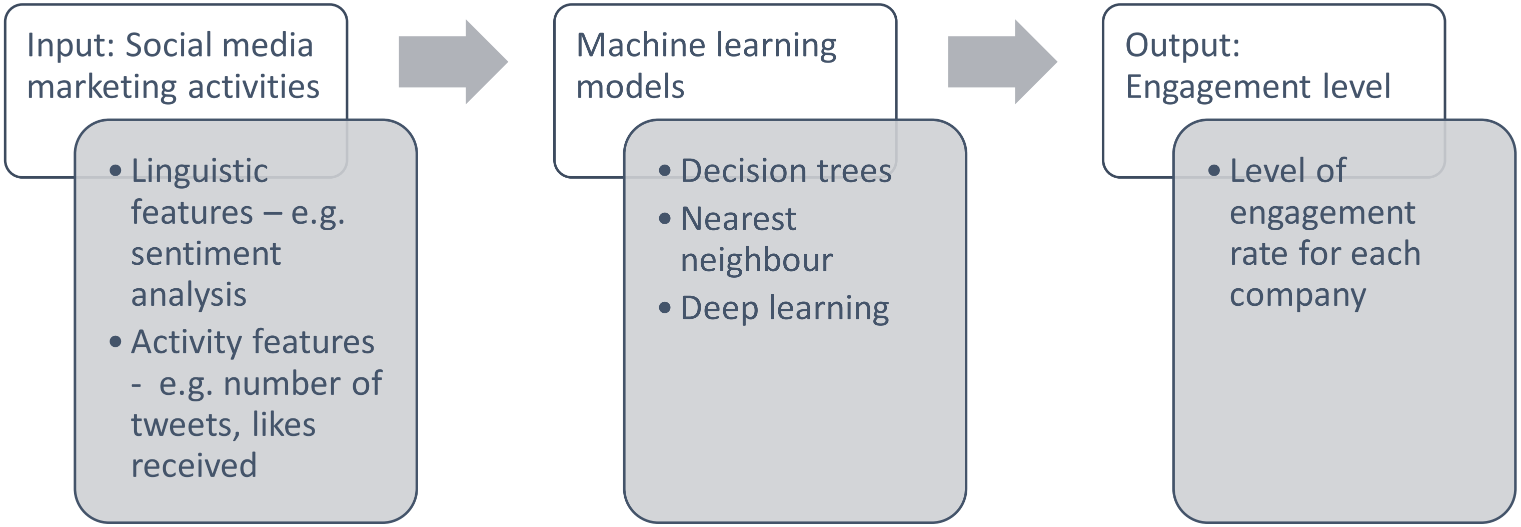
Management and Finance

- Presents Researches For Applying Machine Learning Techniques to Management and Finance Analysis

2.1 Social Media Marketing Analysis

Formal Published Paper Title: Twitter data analytical methodology development for prediction of start-up firms' social media marketing level, 2020

- Method of social media engagement level prediction
- A methodology with data science approaches, such as data collection, machine learning, and deep learning



Input: Social media marketing activities

- Linguistic features – e.g. sentiment analysis
- Activity features - e.g. number of tweets, likes received

Machine learning models

- Decision trees
- Nearest neighbour
- Deep learning

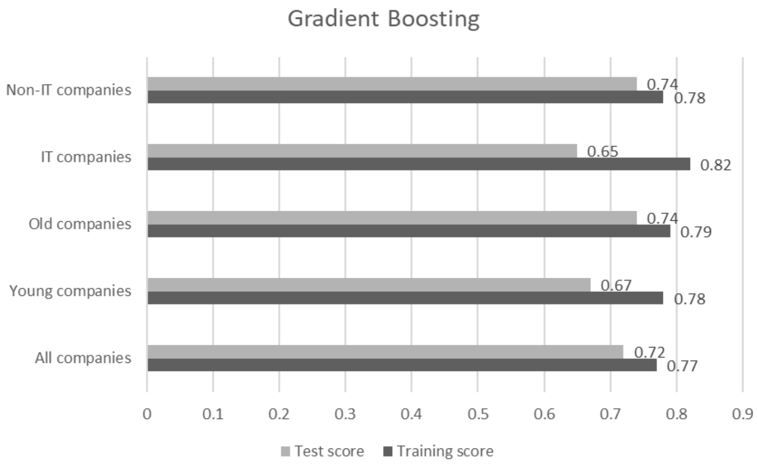
Output: Engagement level

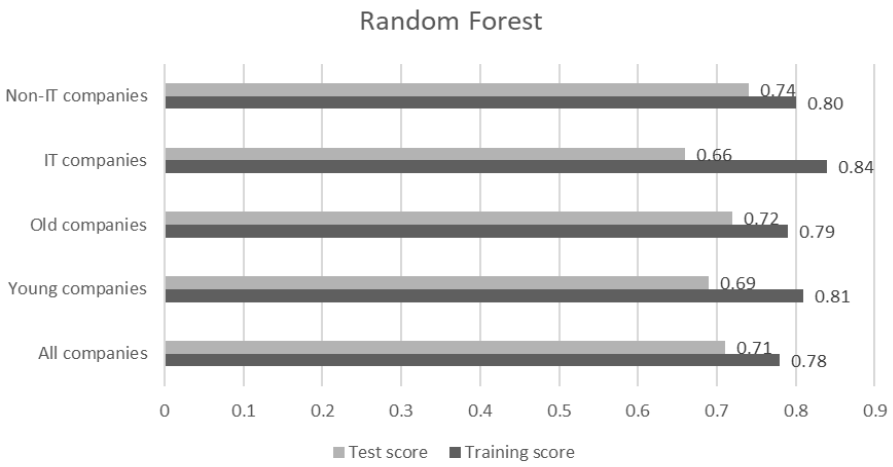
- Level of engagement rate for each company

2.2 Quantitative Perspective of Industry Forces

Formal Research Title: A quantitative perspective of Porter’s industry forces framework for investment analysis, 2020

- NASDAQ exchange firms (classified to 5 types)
- Features a representation of quantitative perspective on Porter’s industry forces (industry’s weakness and strength)
- Business performance (strategy) prediction using quantitative representation of industry forces


Gradient Boosting


Random Forest

3

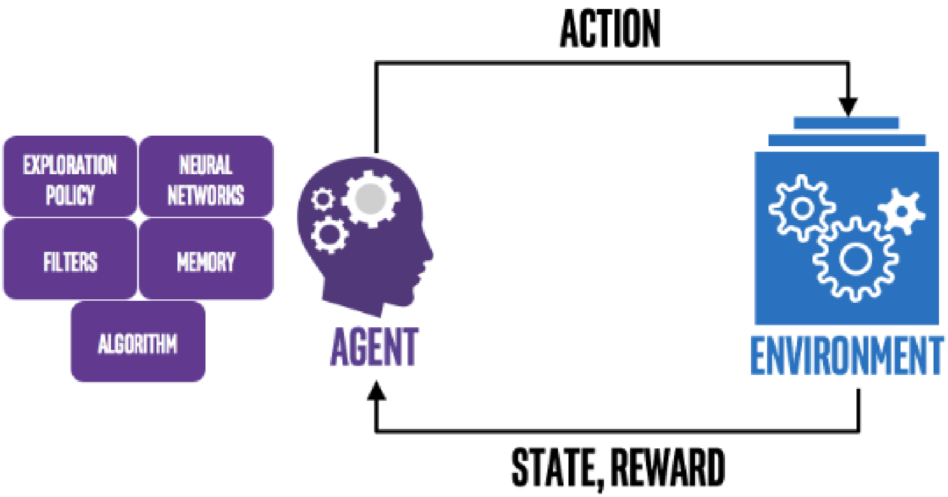
Reinforcement Learning

- Presents Researches For Applying Reinforcement Learning Techniques to Practical Problems

Primer on Reinforcement Learning

Reinforcement Learning (RL)

- Concerned with sequential decision making process
- Features an agent learning how to act or decide in an environment

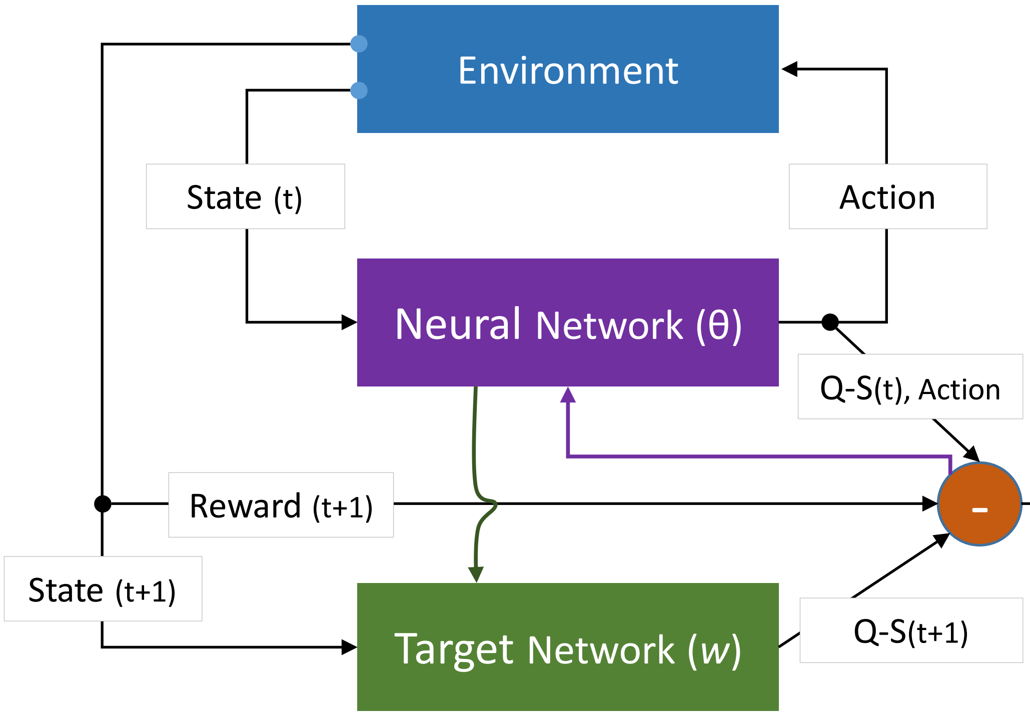

ACTION
EXPLORATION POLICY
NEURAL NETWORKS
FILTERS
MEMORY
ALGORITHM
AGENT
ENVIRONMENT
STATE, REWARD

- **Agent** – The program to train (Neural network)
- **Environment** – The world (real or virtual), in which the agent performs actions
- **State** – How the agent sees the environment
- **Action** – A move made by the agent, which causes a status change in the environment
- **Rewards** – The evaluation of an action, which can be positive or negative

Primer on Reinforcement Learning

General Flow of Reinforcement Learning

- Deep Q-Network (DQN) Perspective


Environment
State (t)
Action
Neural Network (θ)
Q-S(t), Action
Reward (t+1)
-
State (t+1)
Target Network (*w*)
Q-S(t+1)

1. Input S(t) to NN(θ) then outputs an action
2. From the Action, Environment gives S(t+1) and R(t+1)
3. TN(*w*) computes Q-S(t+1), then computes the loss function
4. The loss function is used to train NN(θ)
5. Purple arrow indicates the parameter update (learning) of NN(θ)
6. After tens or hundreds of NN(θ) update, Green arrow indicates parameters copy to TN(*w*)

Loss:

$$(R_{t+1} + \gamma maxQ(S_{t+1}) - Q(S_t, A))^2$$

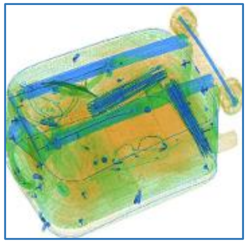
3.1 RL Method for Imbalanced Classification

Formal Research Title: Synchronous Actor-Critic for Imbalanced Classification Problem

- Method to train a deep neural network classifier directly from imbalanced data
- Actor-critic network is suggested to handle complex, high-dimensional data

State:
Image pixels or features of the sample.

Action:
0 – negative (no threat)
1 – positive (with threat)



E.g. Resized x-ray image (224 x 224 x 3)

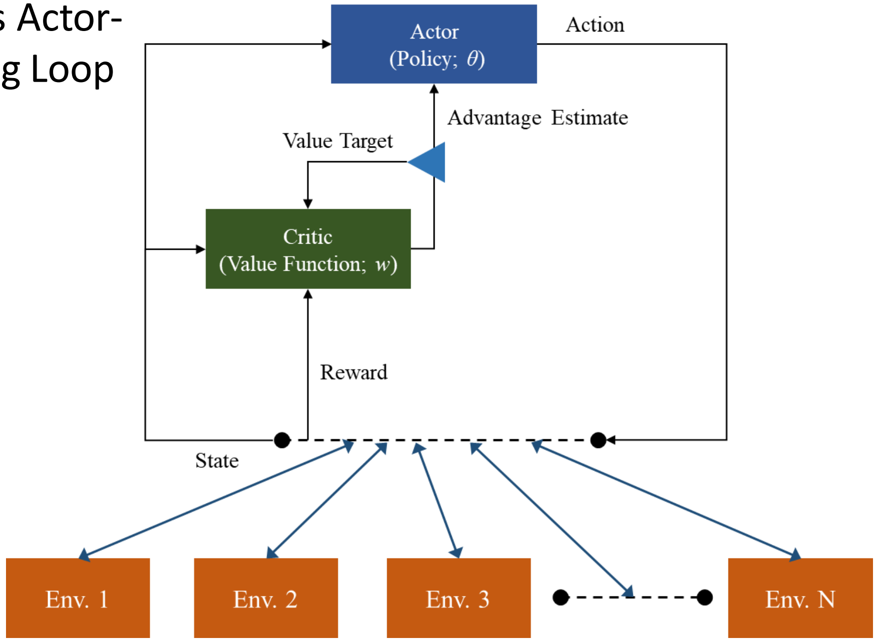
Reward:
- For negative samples: (**1** = Imbalance ratio)

+**1** : true label = action (predicted class)
−**1** : true label ≠ action

- For positive samples:

+1 : true label = action (predicted class)
−1 : true label ≠ action

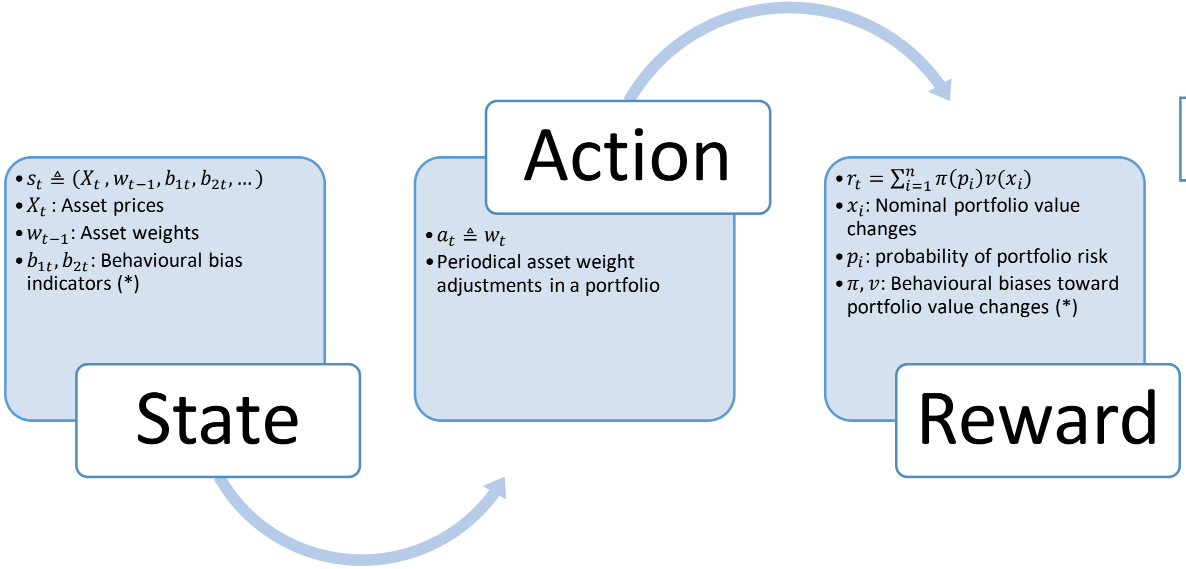
- Synchronous Actor-Critic Training Loop


Actor
(Policy; θ)
Action
Advantage Estimate
Value Target
Critic
(Value Function; w)
Reward
State
Env. 1
Env. 2
Env. 3
Env. N

3.2 Portfolio Management with RL

Formal Research Title: Behavioral Portfolio Management with Reinforcement Learning

- Incorporated behavioural finance concepts into portfolio management process
- Provides a more realistic model to follow



State

- $s_t \triangleq (X_t, w_{t-1}, b_{1t}, b_{2t}, \dots)$
- X_t : Asset prices
- w_{t-1}: Asset weights
- b_{1t}, b_{2t}: Behavioural bias indicators (*)

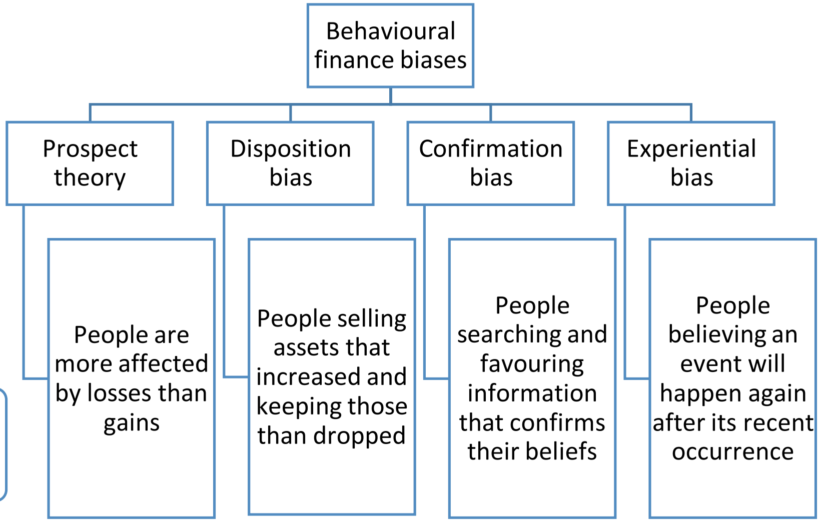
Action

- $a_t \triangleq w_t$
- Periodical asset weight adjustments in a portfolio

Reward

- $r_t = \sum_{i=1}^{n} \pi(p_i) v(x_i)$
- x_i: Nominal portfolio value changes
- p_i: probability of portfolio risk
- π, v: Behavioural biases toward portfolio value changes (*)

- Reinforcement Learning Workflow



Behavioural finance biases

- Prospect theory
  - People are more affected by losses than gains
- Disposition bias
  - People selling assets that increased and keeping those than dropped
- Confirmation bias
  - People searching and favouring information that confirms their beliefs
- Experiential bias
  - People believing an event will happen again after its recent occurrence

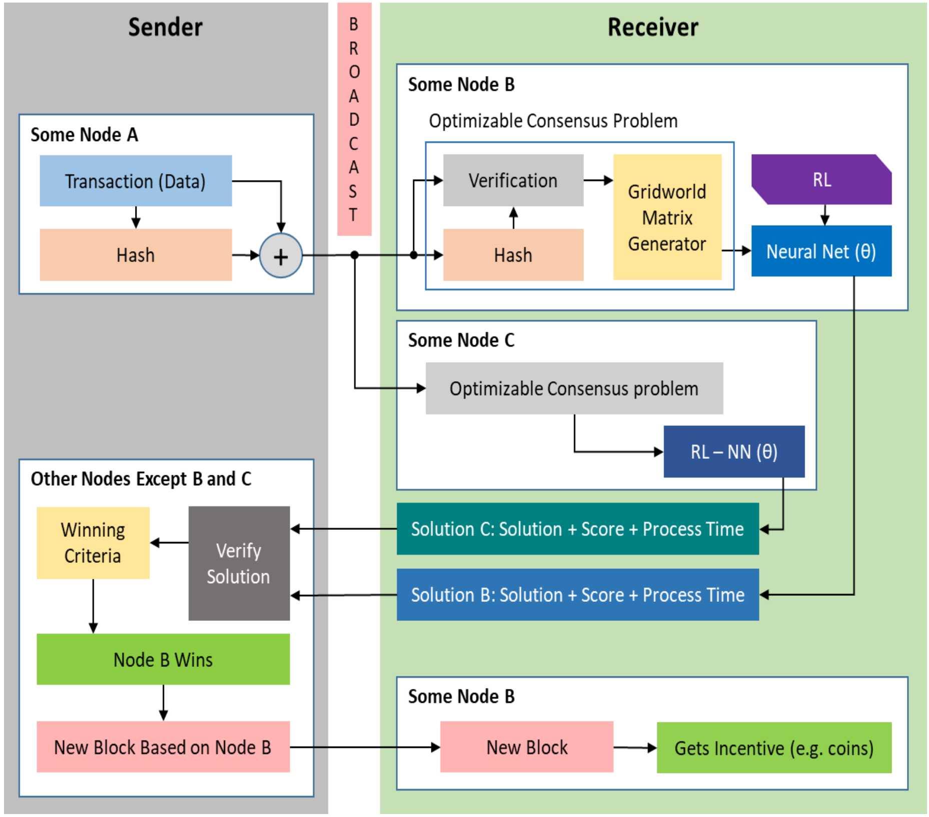
- Behavioural Finance Biases

3.3 RL and Blockchain Convergence

Formal Research Title: Exploring Reinforcement Learning Techniques to Decentralized AI Networks

- The study explores an AI-specific consensus protocol to decentralized AI networks
- Techniques on reinforcement learning are utilized to solve the consensus problem to alleviates inherent disadvantages and vulnerabilities in current blockchain
- Global Process

1. Initiate Transaction
2. P2P Broadcast
3. Solving Consensus Problem
4. Competitive Broadcast and Validation
5. New Block Creation



Sender

Receiver

BROADCAST

Some Node A

Transaction (Data)

Hash

+

Some Node B

Optimizable Consensus Problem

Verification

Hash

Gridworld Matrix Generator

RL

Neural Net (θ)

Some Node C

Optimizable Consensus problem

RL – NN (θ)

Solution C: Solution + Score + Process Time

Solution B: Solution + Score + Process Time

Other Nodes Except B and C

Winning Criteria

Verify Solution

Node B Wins

New Block Based on Node B

Some Node B

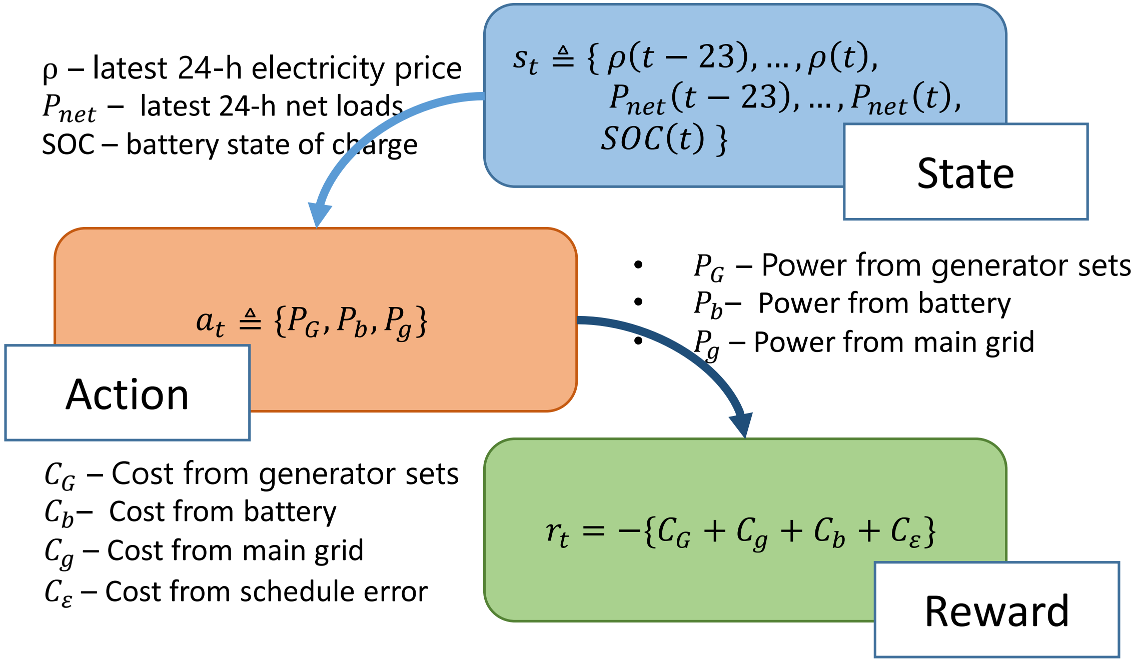
New Block

Gets Incentive (e.g. coins)

- Example Detailed Node Process

RL for Multi-source Power Management

- Use reinforcement learning for scheduling multiple power source
- Through reinforcement learning, the scheduling considers implicitly the uncertainty of the load demand, renewable energy and electricity price, rather than creating a dedicated predictor to estimate the uncertainty



- ρ – latest 24-h electricity price
- P_{net} – latest 24-h net loads
- SOC – battery state of charge

$$s_t \triangleq \{\, \rho(t-23), \dots, \rho(t), P_{net}(t-23), \dots, P_{net}(t), SOC(t) \,\}$$

State

$$a_t \triangleq \{P_G, P_b, P_g\}$$

Action

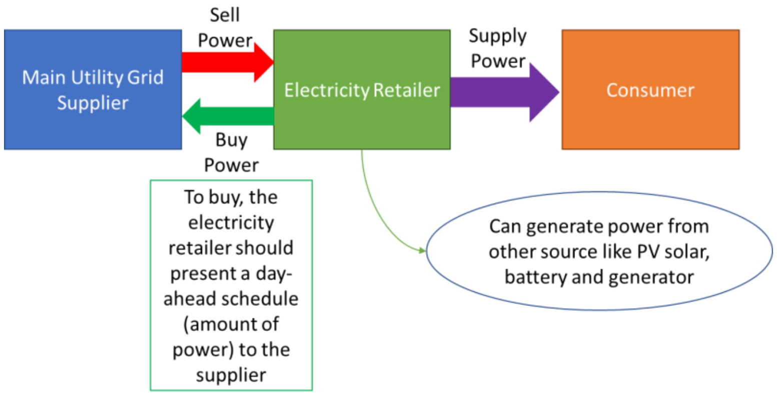
- P_G – Power from generator sets
- P_b – Power from battery
- P_g – Power from main grid

- C_G – Cost from generator sets
- C_b – Cost from battery
- C_g – Cost from main grid
- C_ε – Cost from schedule error

$$r_t = -\{C_G + C_g + C_b + C_\varepsilon\}$$

Reward

- Reinforcement Learning Workflow



To buy, the electricity retailer should present a day-ahead schedule (amount of power) to the supplier

Can generate power from other source like PV solar, battery and generator

- Supplier-Retailer Operation

Recent Research Papers

Recently Published Research Papers:

1. V. J. Montero and Y. J. Jeong, "Development of License Plate Recognition on Complex Scene with Plate-Style Classification and Confidence Scoring Based on KNN," IEICE Transactions on Information and Systems, Vol. E101-D, No. 12, pp. 3181-3189, Dec. 2018.
2. V. J. Montero, W. Y. Jung, Y. J. Jeong, “Fast Background Subtraction with Adaptive Block Learning Using Expectation Value Suitable for Real-time Moving Object Detection”, Journal of Real-Time Image Processing (JRTIP), https://doi.org/10.1007/s11554-020-01058-8, Jan. 2021.
3. V. J. Montero, W. Y. Jung, Y. J. Jeong, “Solving Survival Gridworld Problem Using Hybrid Policy Modified Q-Based Reinforcement”, Institute of Korean Electrical and Electronics Engineers (IKEEE), Vol. 23 No. 4, pp. 1150-1156, Dec. 2019.
4. J. K. Dumagpi, W. Y. Jung, Y. J. Jeong, “A New GAN-Based Anomaly Detection (GBAD) Approach for Multi-Threat Object Classification on Large-Scale X-Ray Security Images”, IEICE Transactions on Information and Systems, Vol. E102-D No. 2, pp. 454-458, Feb. 2020.
5. J. K. Dumagpi, W. Y. Jung, Y. J. Jeong, “KNN-Based Automatic Cropping for Improved Threat Object Recognition in X-Ray Security Images”, Institute of Korean Electrical and Electronics Engineers (IKEEE), Vol. 23, No. 4, pp. 1134-1139, Dec. 2020.

Recent Research Papers

Recently Published Research Papers:

6. S. H. Jung and Y. J. Jeong, “Twitter Data Analytical Methodology Development for Prediction of Start-up Firm’s Social Media Marketing Level”, Technology in Society, Vol. 63, Article 101409, Nov. 2020.
7. A. J. Tiempo, W. Y. Jung, and Y. J. Jeong, “Employing Linear Feedback Shift Register as a New Hardware Trojan and Extending ML-FASTrust Method as its Detection Algorithm”, Journal of Semiconductor Technology and Science (JSTS), IEIE Vol. 20 No. 2, pp. 214-219, Apr. 2020.
8. J. K. Dumagpi and Y. J. Jeong, “Evaluating GAN-based Image Augmentation for Threat Detection in Large-Scale Xray Security Images”, Applied Sciences, https://dx.doi.org/10.3390/app11010036, Dec. 2020

Research Papers Under Revision/Preparation:

1. V. J. Montero and Y. J. Jeong, “Synchronous Actor Critic for Imbalanced Classification Problem”; Status: Paper on preparation and to be submitted at Applied Intelligence.
2. S. H. Jung and Y. J. Jeong, “A Quantitative Framework for Investment Analysis”; Status: Under going review at Managerial and Decision Economics.