Introduction to data driven smart factory

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The 4th Industrial Revolution

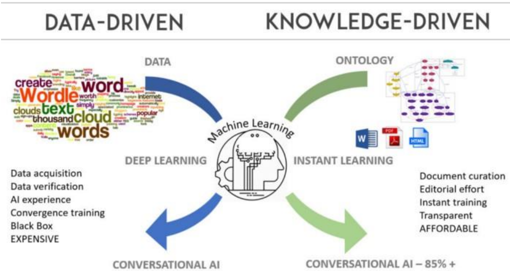
- ICBM, ABCD, AI-ICBM
- Smart factory
- AI
- Robot
- Bio

사진출처:조선일보

Data driven approach

- Data resistant
  - Make data as a priority
- Data aware
  - Data being generated
  - Realize the value of data
- Data guided
  - Focus on data analysis
  - Realize tactical value of data
- Data savvy
  - Realize the strategic value of data
  - Self-service data science
- Data driven
  - Data is made available to all
  - Every major decision is made completely backed by data evidence
  - Data becomes the language of conversation between teams

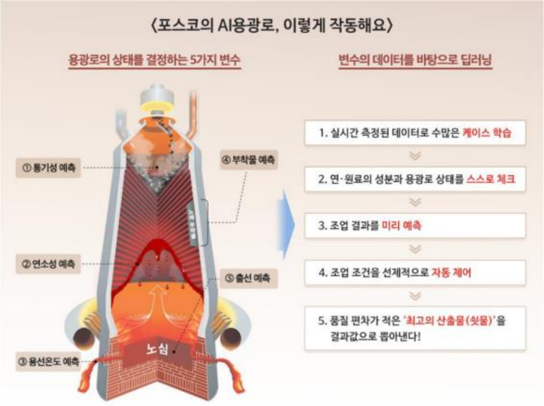
By dataQraft, 2020.09

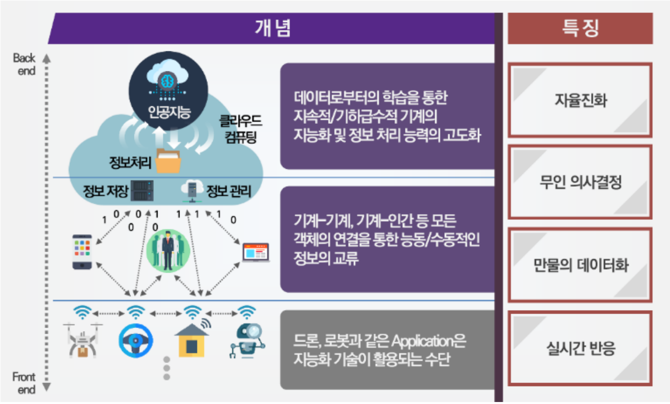


Data driven approach

- Things to be required
  - Data base
  - Data structures and algorithm
  - Data mining
  - Deep learning and AI

Data driven approach





What is ML and AI?

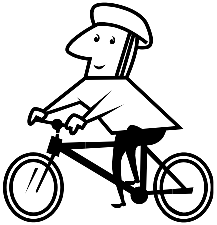
- ML
  - To Make Machine 'Learn': 기계가 학습을 하도록
- AI
  - 인공적으로 만들어진 지능

Artificial intelligence (**AI**), sometimes called **machine intelligence**, is intelligence demonstrated by machines, in contrast to the **natural intelligence** displayed by humans and other animals. (from Wikipedia)

What is learning

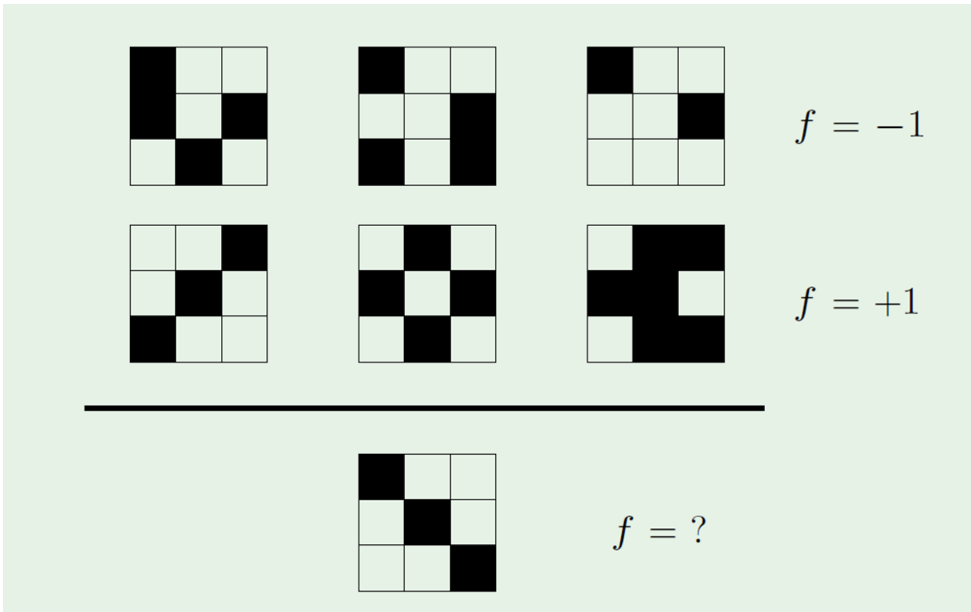
- Learning
  - A process that allows an agent to adapt its performance through instruction or experience
  - Considered fundamental to intelligent behavior
  - May be
    - Simple association task
      - A specific output is required when given some input
    - Acquisition of a skill

> changes in a system that are adaptive in the sense that they enable the system to do the same task or tasks drawn from the same population more efficiently and more effectively next time.



- Why?
  - Very active and large area of AI
  - Biological and cognitive perspective
    - Desire to understand more about our selves
  - Get machines to perform tasks that serve us in some way

Quiz #1: What is f?

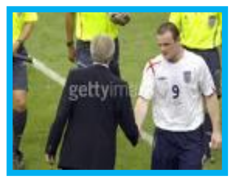


Quiz #2: What is A, and what is B?

"A people bow but B people shake hands





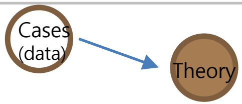



Quiz #3: What is y?

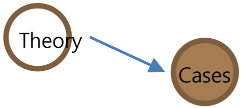
- $y=f(x) = x!$
  - $f(3) = ?$
- $y=f(x) = 3x+2$
  - $f(1)=?$
- $f(1)=5, f(2)=8,$
  - $f(3)=?$

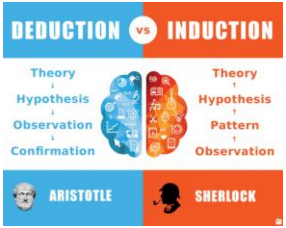
Inductive vs. Deductive

- Induction(귀납): Specific to General
  - A dies, B dies, C dies, …
  - Everybody dies.



- Deduction(연역): General to specific
  - Every man dies. Socrates is a man.
  - Socrates dies.





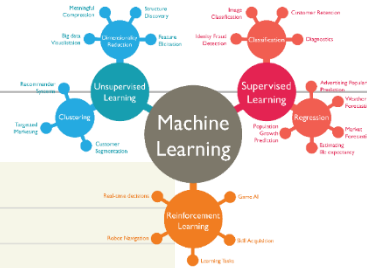
Deductive

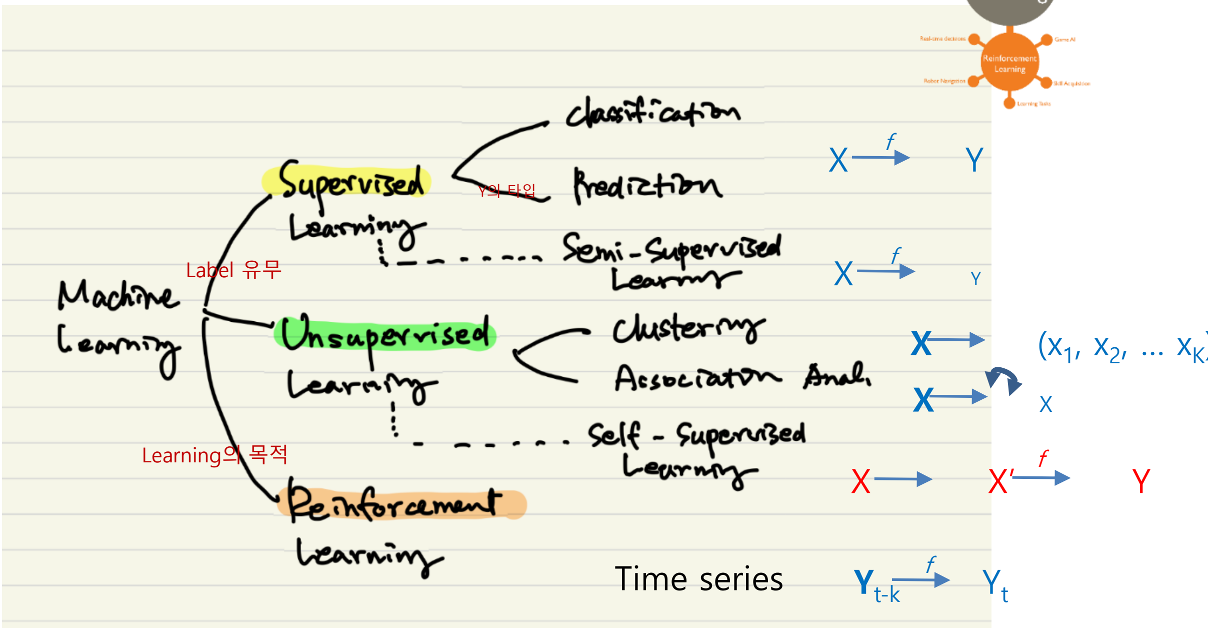
```
girl(sunae).
boy(jungbae).
rich(jungbae).
pretty(sunae).
likes(X, Y):- girl(X), boy(Y), rich(Y).
likes(X, Y):- boy(X), girl(Y), pretty(Y).
```

- |?- likes(jungbae, sunae).

Learning method

- Traditional learning





- Deep learning
- Reinforcement learning

- Supervised vs. Unsupervised
  - Supervised learning
    - learning from training instances of known classification
  - Unsupervised learning
    - learning from unclassified training data
    - conceptual clustering or category formation
  - Reinforcement learning

What is (Machine) learning?

- Finding '*f*' such that

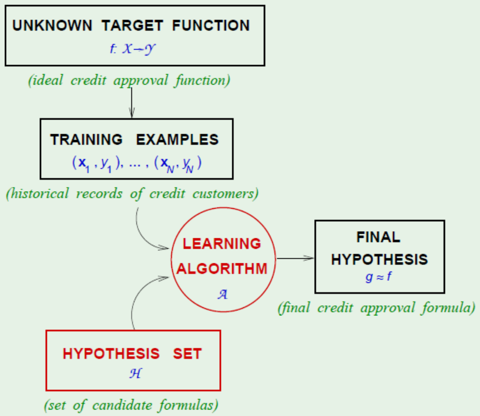
$$Y = f(X)$$

rule
pattern
knowledge

- We use X and Y to find '*f*'

- Types of learning tasks
  - Classification learning
    - Example: optically scanning and automatically recognizing hand-printed character
  - Learning sequence of actions
    - Chess game and robots that navigate around offices emptying bins.
  - Learning optimal decisions
  - Learning regression function
    - Learning the association between variables
  - Learning programs
    - Specifically targeted at learning to represent the solution of a task

Components of learning



Formalization:

- Input: $\mathbf{x}$ (*customer application*)
- Output: y (*good/bad customer?*)
- Target function: $f : \mathcal{X} \to \mathcal{Y}$ (*ideal credit approval formula*)
- Data: $(\mathbf{x}_1, y_1), (\mathbf{x}_2, y_2), \cdots, (\mathbf{x}_N, y_N)$ (*historical records*)

$\downarrow \quad \downarrow \quad \downarrow$

- Hypothesis: $g : \mathcal{X} \to \mathcal{Y}$ (*formula to be used*)

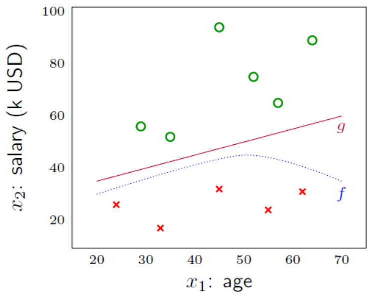
- Elements of learning
  - Algorithm
    - Define the process that is used for learning
    - Transform input data into a particular form of useful output
  - Target function
    - The product of learning
  - Training

$$\mathbf{W} \leftarrow \mathbf{W} + c(d - f)\mathbf{X}$$

Weigh update	=	Direction reducing err. **(decent)**	x	Size of one step **(learning rate)**	x	slope **(gradient)**
$-\eta \nabla_\theta J(\theta)$		$-$		η		$\nabla_\theta J(\theta)$

PLA (Perceptron)

n	x_1	x_2	y
1	29	56k	approve
2	64	89k	approve
3	33	17k	deny
4	45	94k	approve
5	24	26k	deny
6	55	24k	deny
7	35	52k	approve
8	57	65k	approve
9	45	32k	deny
10	52	75k	approve
11	62	31k	deny



For input $\mathbf{x} = (x_1, \cdots, x_d)$ 'attributes of a customer'

$$\text{Approve credit if} \quad \sum_{i=1}^{d} w_i x_i > \text{threshold},$$

$$\text{Deny credit if} \quad \sum_{i=1}^{d} w_i x_i < \text{threshold}.$$

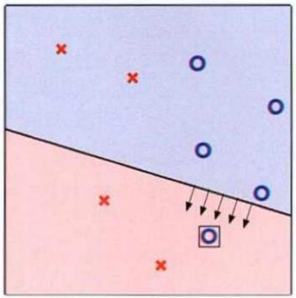
This linear formula $h \in \mathcal{H}$ can be written as

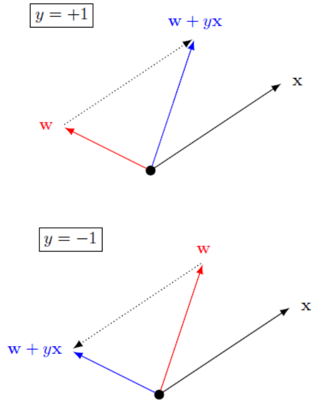
$$h(\mathbf{x}) = \text{sign}\left(\left(\sum_{i=1}^{d} w_i x_i\right) - \text{threshold}\right)$$

How to make 'P' learn

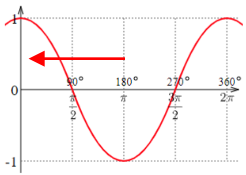
- PLA (Perceptron Learning Algorithm)

$$\mathbf{w}(t+1) = \mathbf{w}(t) + y(t)\mathbf{x}(t).$$





$$w^T x$$



The weight update rule in (1.3) has the nice interpretation that it moves in the direction of classifying $\mathbf{x}(t)$ correctly.

(a) Show that $y(t)\mathbf{w}^{\mathsf{T}}(t)\mathbf{x}(t) < 0$. *[Hint: $\mathbf{x}(t)$ is misclassified by $\mathbf{w}(t)$.]*

(b) Show that $y(t)\mathbf{w}^{\mathsf{T}}(t+1)\mathbf{x}(t) > y(t)\mathbf{w}^{\mathsf{T}}(t)\mathbf{x}(t)$. *[Hint: Use (1.3).]*

(c) As far as classifying $\mathbf{x}(t)$ is concerned, argue that the move from $\mathbf{w}(t)$ to $\mathbf{w}(t+1)$ is a move 'in the right direction'.

The Widrow-Hoff Procedure

- Weight update procedure:
  - Using $f = s = \mathbf{W} \cdot \mathbf{X}$
  - Data labeled $1 \rightarrow 1$, Data labeled $0 \rightarrow -1$
- Gradient: if f =s,

$$\frac{\partial \varepsilon}{\partial \mathbf{W}} = -2(d - f)\frac{\partial f}{\partial s}\mathbf{X} = -2(d - f)\mathbf{X}$$

- New weight vector

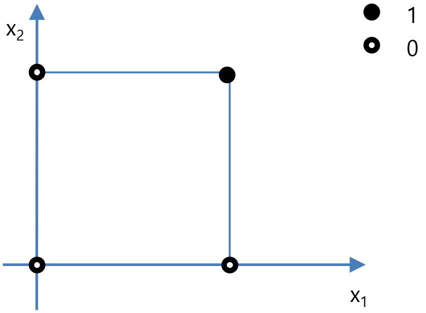
$$\mathbf{W} \leftarrow \mathbf{W} + c(d - f)\mathbf{X}$$

- Widrow-Hoff (delta) rule
  - $(d - f) > 0 \rightarrow$ increasing $s \rightarrow$ decreasing $(d - f)$
  - $(d - f) < 0 \rightarrow$ decreasing $s \rightarrow$ increasing $(d - f)$

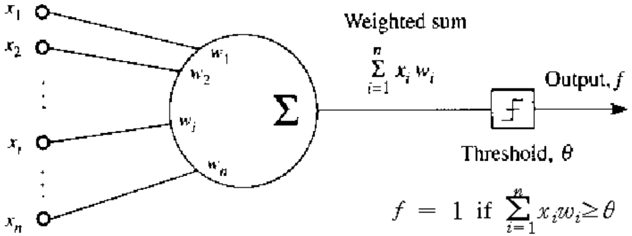
A simple classifier: Perceptron

- Dataset

input		Output (by *f*)		
X_0	X_1	AND	OR	XOR
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0



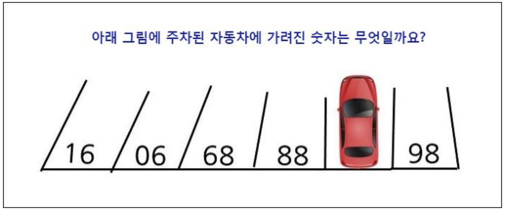
- Perceptron



$$f = 1 \text{ if } \sum_{i=1}^{n} x_i w_i \geq \theta$$
$$= 0 \ \textit{otherwise}$$

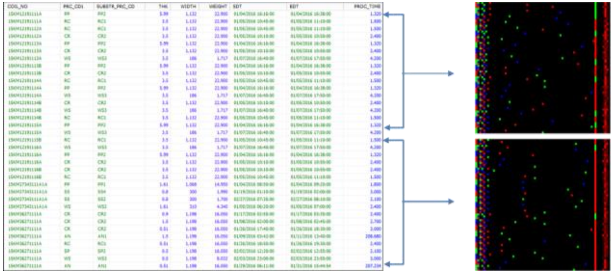
We need data

- 수치형, 범주형
  - (234, 0.327, …) (토요일, 맑음, 배혜림)
- 연속형, 이산형
  - (0.234, 0.327, …) (0, 1)
- 정형, 비정형
  - (Table, 벡터, 리스트), (이미지, 음성, 문서)
- 균형, 비균형
  - 양, 불량

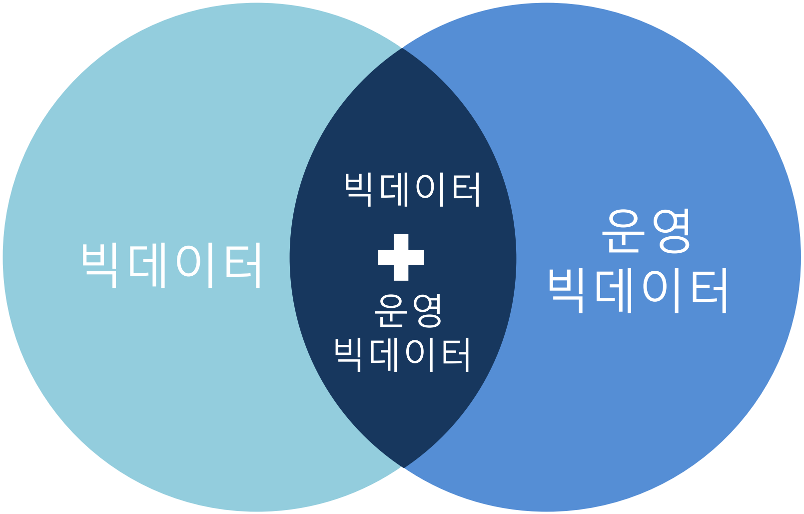


- 기계는 모든 유형의 data를 받아 들일 수 있을까요?

Handling categorical variables
Mixed input/output



Data used for ML



In Port Logistics

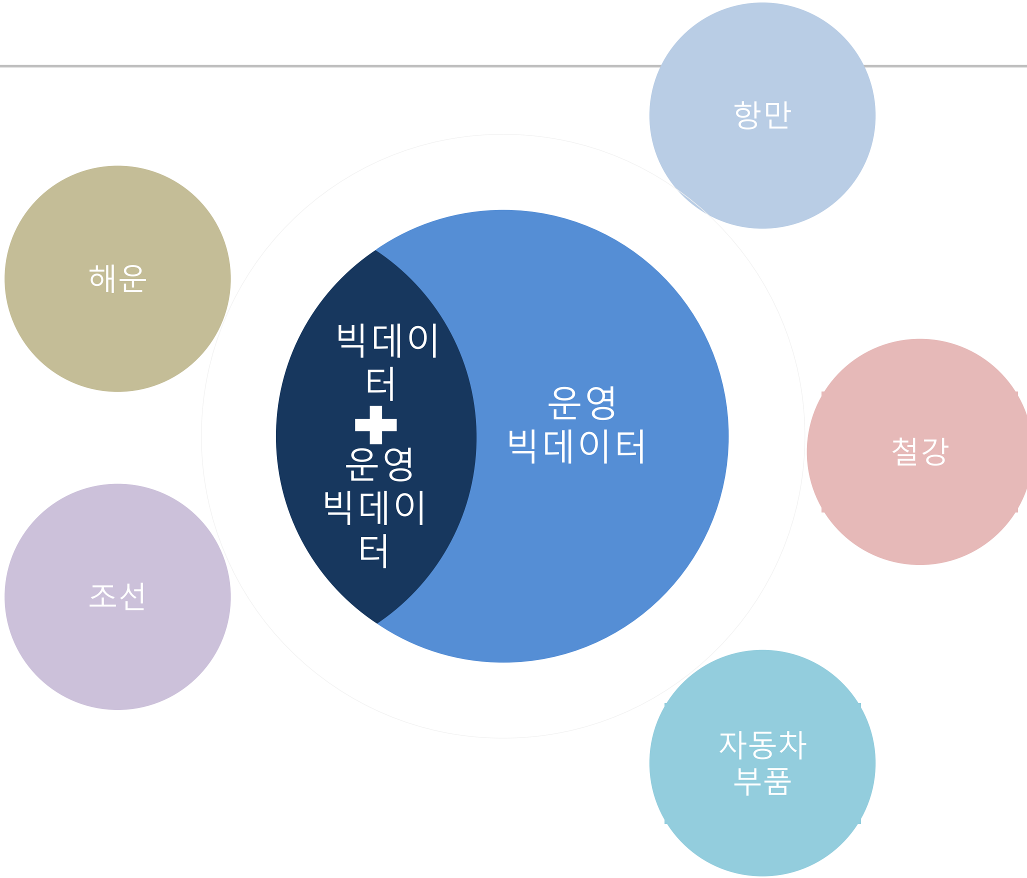
❖ 예) 항만 운영 빅데이터

VESSEL	CONTAINER_NO	MCHN_ID	MCHN_TP_CD	FULL_EMPTY	JOB_TYPE	POD	BLOCK_BAY	JOB_START_DT	JOB_END_DT
ALAP-001/2018	AXIU1484082-2	GC112	QC	F	DS-QUAYSIDE	KRPUS	1B-38	20180131211752	20180131211924
ALAP-001/2018	AXIU1484082-2	TC221	TC	F	DS-YARDSIDE	KRPUS	1B-38	20180131213633	20180131213805
ALAP-001/2018	AXIU1484082-2	YT511	YT	F	DS-MOVE	KRPUS	1B-38	20180131211924	20180131213633
ALAP-001/2018	BEAU2976719-1	GC111	GC	F	LD-QUAYSIDE	CAVAN	2B-19	20180131202120	20180131202353
ALAP-001/2018	BEAU2976719-1	TC223	TC	F	LD-YARDSIDE	CAVAN	2B-19	20180131200147	20180131200420
ALAP-001/2018	BEAU2976719-1	YT511	YT	F	LD-MOVE	CAVAN	2B-19	20180131200420	20180131202120
ALAP-001/2018	BGBU5060490-3	GC109	QC	F	DS-QUAYSIDE	KRPUS	3F-69	20180131205748	20180131205920
ALAP-001/2018	BGBU5060490-3	TC266	TC	F	DS-YARDSIDE	KRPUS	3F-69	20180131211132	20180131211304
ALAP-001/2018	BGBU5060490-3	YT538	YT	F	DS-MOVE	KRPUS	3F-69	20180131205920	20180131211132
ALAP-001/2018	BGBU5062868-1	GC109	QC	F	DS-QUAYSIDE	KRPUS	3F-69	20180131205358	20180131205530

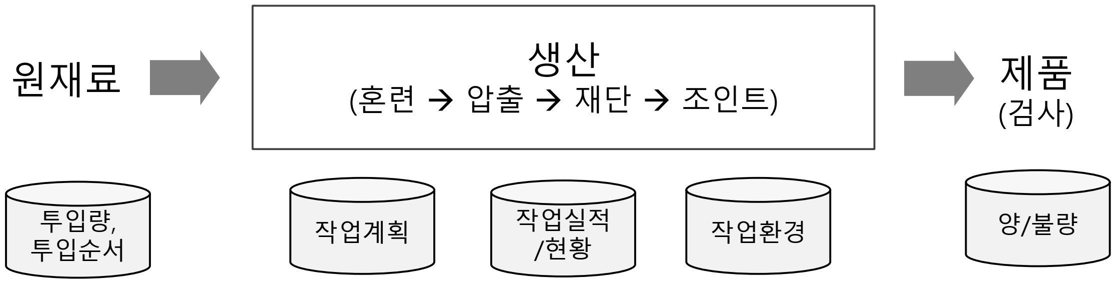
❖ 컨테이너 관점의 데이터 해석

VESSEL	CONTAINER_NO	MCHN_ID	MCHN_TP_CD	FULL_EMPTY	JOB_TYPE	POD	BLOCK_BAY	JOB_START_DT	JOB_END_DT
ALAP-001/2018	AXIU1484082-2	GC112	QC	F	DS-QUAYSIDE	KRPUS	1B-38	20180131211752	20180131211924
ALAP-001/2018	AXIU1484082-2	TC221	TC	F	DS-YARDSIDE	KRPUS	1B-38	20180131213633	20180131213805
ALAP-001/2018	AXIU1484082-2	YT511	YT	F	DS-MOVE	KRPUS	1B-38	20180131211924	20180131213633
ALAP-001/2018	BEAU2976719-1	GC111	GC	F	LD-QUAYSIDE	CAVAN	2B-19	20180131202120	20180131202353
ALAP-001/2018	BEAU2976719-1	TC223	TC	F	LD-YARDSIDE	CAVAN	2B-19	20180131200147	20180131200420
ALAP-001/2018	BEAU2976719-1	YT511	YT	F	LD-MOVE	CAVAN	2B-19	20180131200420	20180131202120
ALAP-001/2018	BGBU5060490-3	GC109	QC	F	DS-QUAYSIDE	KRPUS	3F-69	20180131205748	20180131205920
ALAP-001/2018	BGBU5060490-3	TC266	TC	F	DS-YARDSIDE	KRPUS	3F-69	20180131211132	20180131211304
ALAP-001/2018	BGBU5060490-3	YT538	YT	F	DS-MOVE	KRPUS	3F-69	20180131205920	20180131211132
ALAP-001/2018	BGBU5062868-1	GC109	QC	F	DS-QUAYSIDE	KRPUS	3F-69	20180131205358	20180131205530

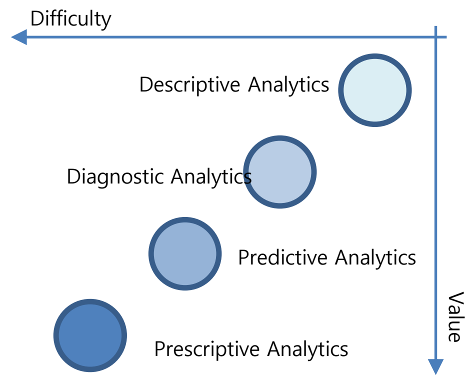
2 무엇을? 1 누가? 3 어떻게? 4 언제?


항만
해운
빅데이터
운영
빅데이터
운영
빅데이터
철강
조선
자동차
부품

데이터 기반 접근법의 단계



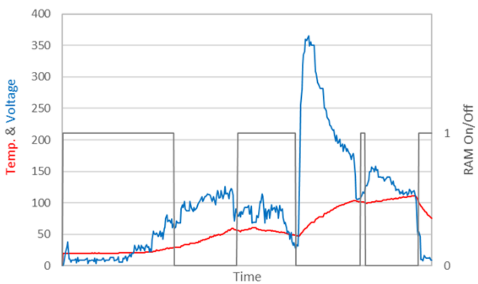
작업현황	**1. Monitoring**
작업이상상황	**2. Detection**
불량의 원인	**4. Diagnosis**
작업완료시간	**3. Prediction**
작업의사결정	**5. Auto control**



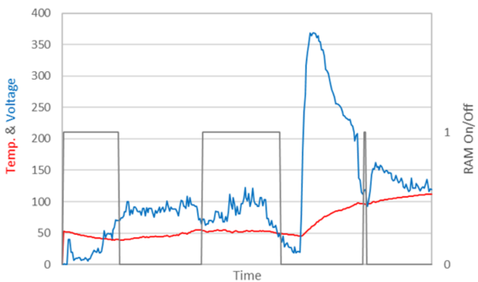
작업현황

- 기계의 현황
- 재고의 현황
- 현재까지의 작업 실적

“14545926-1”.csv

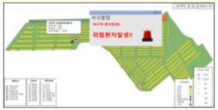


“14626825-9”.csv



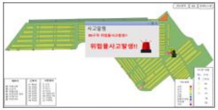
항만에서의 모니터링

[이스탑 모니터링]
중장비 이스탑 발생시 충돌위험 알림 및 이미지 팝업

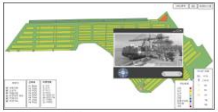


[근로자 건강 모니터링]
항만 근로자의 건강상태 알림

[화재 사고위험 모니터링]
항만의 화재 사고위험 발생시 알림



[위험물 누출 사고위험 모니터링]
항만의 위험물 누출 사고위험 발생시 알림

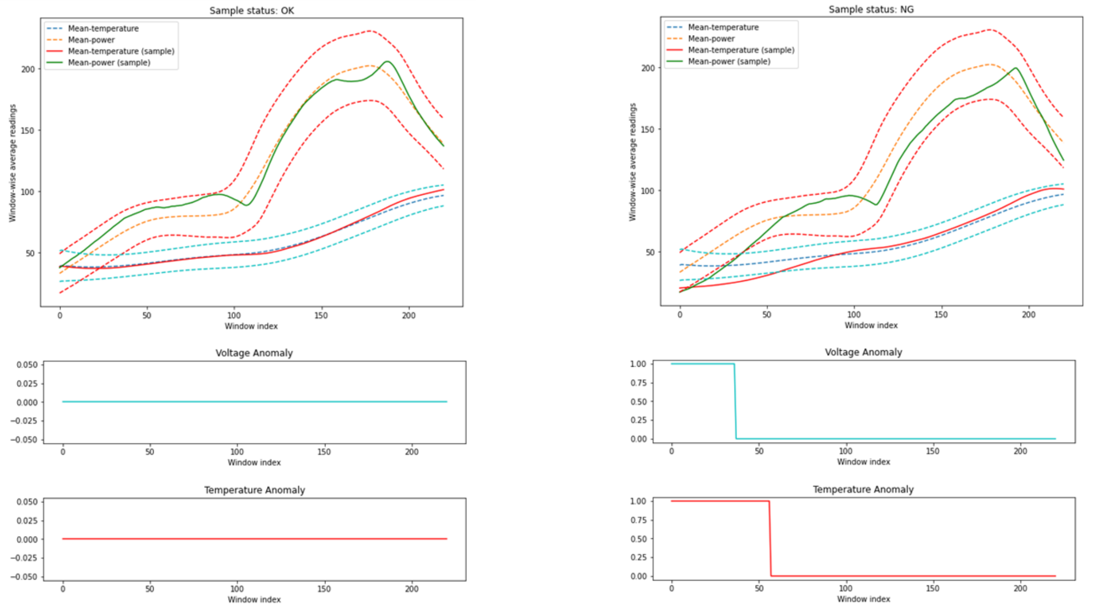


[안전 CCTV 연계]
안전사고 발생시 제일 가까운 CCTV 영상 팝업

[실시간 안전지도 및 사고 예측]
항만 실시간 사고위험도 및 예측 모니터링 가능한 기능

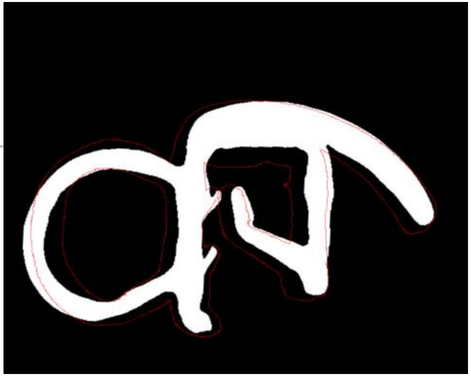
- SafePort 3D 모니터링 시스템

작업의 이상상황



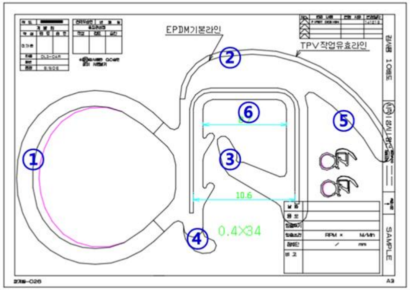
Sample status: OK
Mean-temperature
Mean-power
Mean-temperature (sample)
Mean-power (sample)
Window-wise average readings
Window index
Voltage Anomaly
Window index
Temperature Anomaly
Window index
Sample status: NG
Mean-temperature
Mean-power
Mean-temperature (sample)
Mean-power (sample)
Window-wise average readings
Window index
Voltage Anomaly
Window index
Temperature Anomaly
Window index

불량의 원인

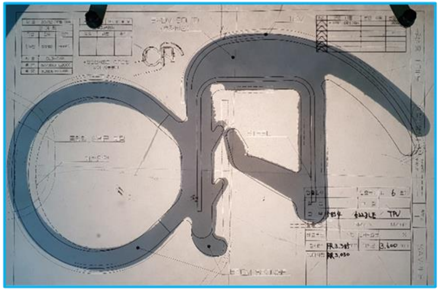


1. 형상 불량 발생 유형 및 주요 제어 조건

▷ 형상 검사 기준

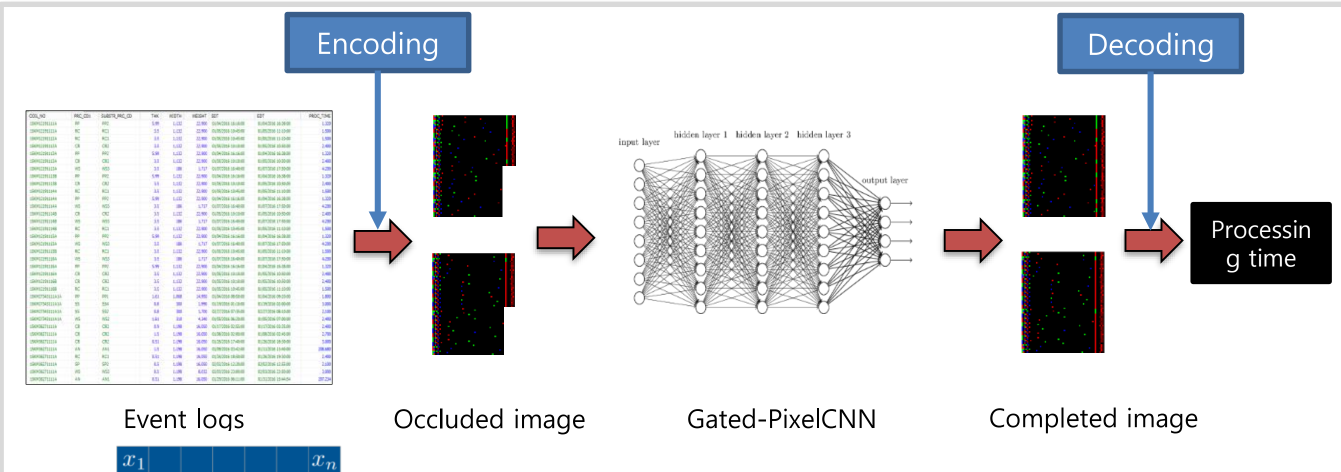


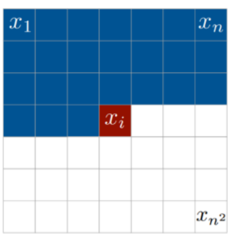
▷ 10배 투영 검사 결과 : 한도견본 수립후 육안검사



주요 관리 부위	불량 유형	주요 제어 조건	사용원재료
① 튜브	튜브 형상 크기/두께 산포, 튜브 상/하단부 변형	AIR 주입 압력, 스폰지 발포, 가이드롤 부착위치	스폰지고무(발포)
② 케리어 상단	두께 산포, 내부 철심금 위치 산포	압출구금 마모, 압출기 스크류 RPM, 프리포밍각도	솔리드고무
③ 그리프	두께/길이 산포, 끝단부 상/하 각도 산포	압출기 스크류 RPM, 단면 이송용 지지롤 간섭, 엠보롤간섭	
④ 수밀립	두께/길이/각도 산포	오븐벨트 속도	
⑤ 트림립	두께/길이 산포, 끝단부 상/하 각도 산포	엠보롤 간섭, 가이드롤 부착위치, 압출고무 무늬	
⑥ 벤딩 내폭	내폭 산포	사이드 벤딩롤 세팅 간격	

작업 완료시간 예측



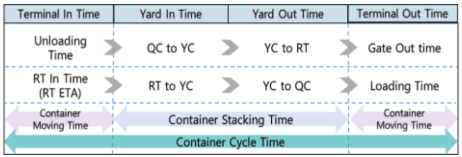


$$p(\mathbf{x}) = \prod_{i=1}^{n^2} p(x_i \mid x_1, ..., x_{i-1}) \qquad (1)$$

$$p(x_{i,R} \mid \mathbf{x}_{<i}) p(x_{i,G} \mid \mathbf{x}_{<i}, x_{i,R}) p(x_{i,B} \mid \mathbf{x}_{<i}, x_{i,R}, x_{i,G}) \quad (2)$$

ML for Smart Operation

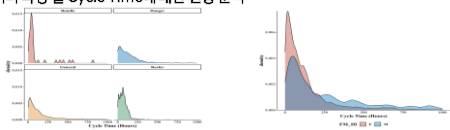
가. 미래 장치장 예측 정의



- 수출입 컨테이너에 따른 Container Cycle Time, Moving Time, Stacking Time 정의
- 야드 적재량 예측을 통한 야드 운영 계획 효율성 증대 및 미래 혼잡도 계산 기반 마련

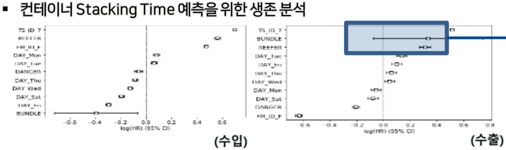
나. 분석 방법

- 컨테이너 특성 별 Cycle Time에 대한 현황 분석



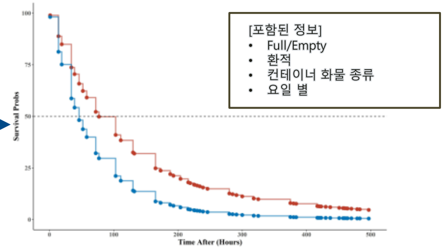
컨테이너 특성에 따른 컨테이너 물량 및 Cycle time 현황

- 컨테이너 Stacking Time 예측을 위한 생존 분석



생존 분석을 통해 변수들의 유의성을 판단(영점 기준 오른쪽-유 의미)

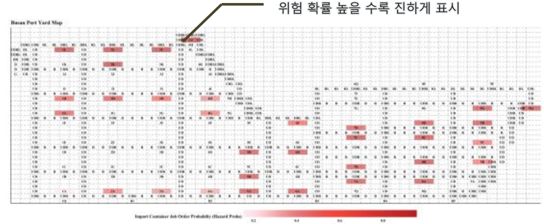
- 생존 분석을 활용한 컨테이너 속성 별 HR Ratio



환적의 영향이 가장 크기 때문에, 환적의 유무로 HR Ratio가 표현

다. 분석 결과

위험 확률 높을 수록 진하게 표시



생존 분석을 통한 야드 적재량 확률을 색의 진함에 따라 Grid화 표현

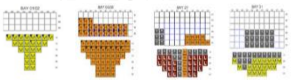
ML for Smart Operation

가. QC 작업 패턴 분석 정의

- 현재 TOS에서는 본선 작업 계획(Crane Working Plan)을 구성할 때, 양/적하 작업 수량에 따른 단순 산출 형식(Ex, 양하 * 1.5분, 적하 * 2.5분)으로 본선 작업을 계획하고 있음
- 이러한 단순 산출 형식은 실제 본선 작업 중에 잦은 Schedule 변경과 Yard Crash 등의 항만 생산성 저하 문제를 야기하고 있음
- 본선 작업 시에 더 정교한 CWP를 구성할 수 있다면, 항만 터미널 생산성을 증가시킬 수 있는 효과가 있음
- 본선 작업 시 컨테이너의 특성을 반영하여 QC(CC)의 작업 예상완료시간(ETC)을 더 정교하게 예측함을 통해, 본선 작업 예상시간(ETW)의 정확성을 높여 항만 생산성을 증가시키는 것이 목적

나. QC 작업 패턴 분석 방법

- 본선 작업 스케쥴 정리 기법



각 선박에 대한 Bay Cluster 추출

- ETW를 기반으로 본선 작업의 총 시간 예측

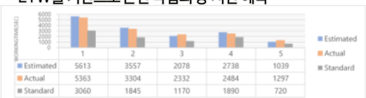


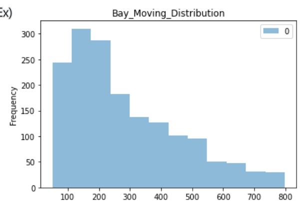
Figure 9 Comparison of Estimated, Actual, and Standard method.

[성능 지표]

- 371개 선박 Schedule에 대한 평가 진행
- 예측 오차 평균 50.8% 감소
- 기존 산술 방식 : Median 기준 3.46 시간의 오차 발생
- 제안된 방법론 : Median 기준 1.56 시간의 오차 발생
- Yard Crash 발생 예측 정확성 향상

- 본선 작업에서의 QC의 작업 특성 별 ETC 분포 도출

Ex)



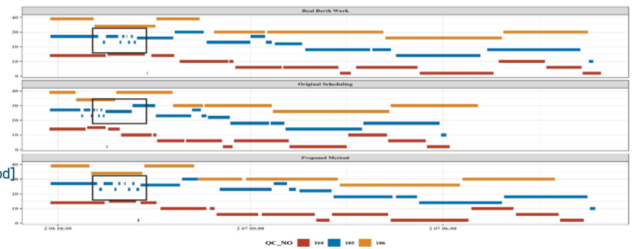
Type, F/M, 작업자 변경, Bay 변경 등의 조건을 고려한 QC의 ETC 분포 기반 ETC 예측

- 도출된 스케쥴의 예상 작업시간 완료를 기준으로 ETW 예측

[Real Berth Work]

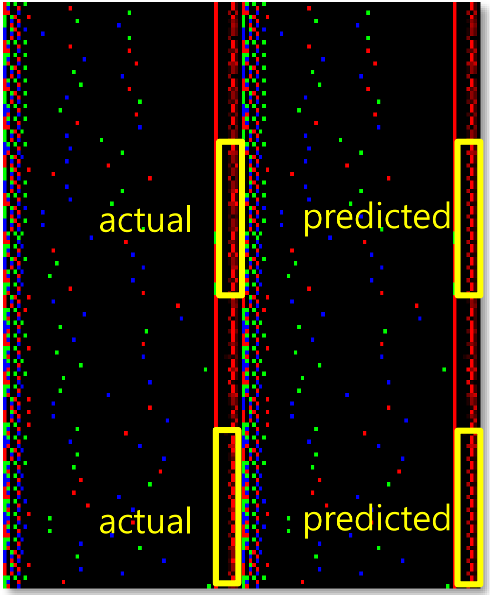
[Original Scheduling]

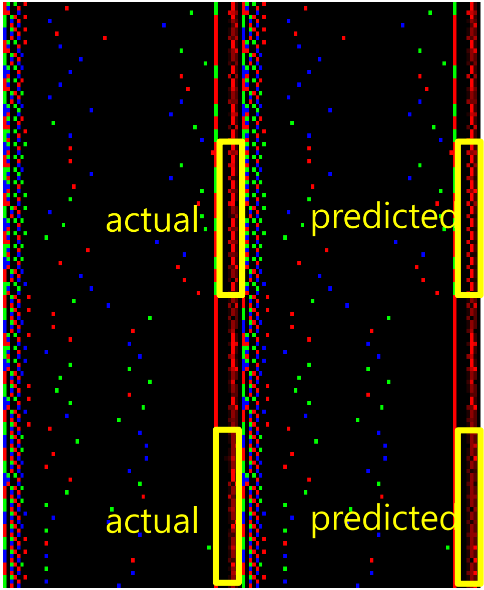
[Proposed Method]



시간 대 별로 시각화 했을 때, Original Scheduling에 비해 본 연구의 제안 방법이 탐지 및 예측력이 우수함

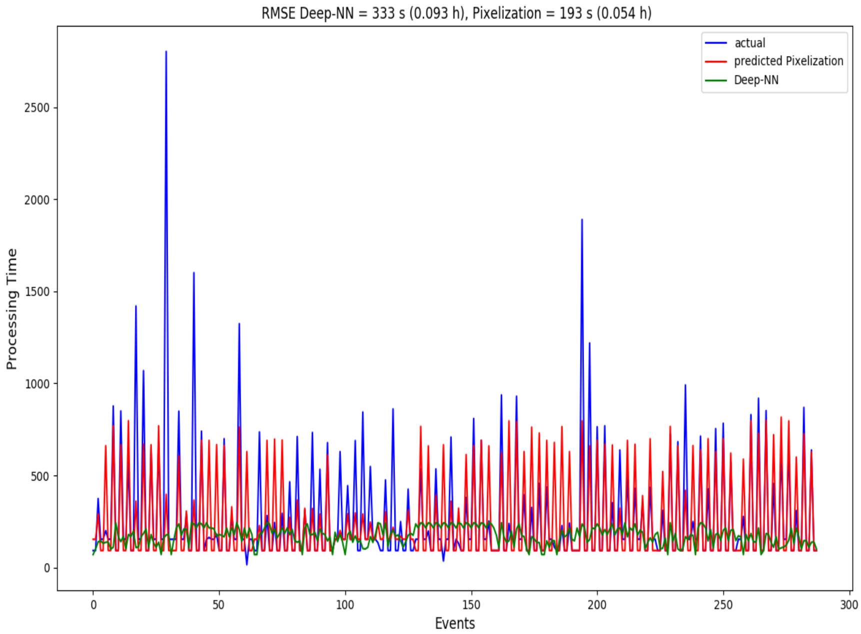
Experimental Result (1)





Experimental Result (2)

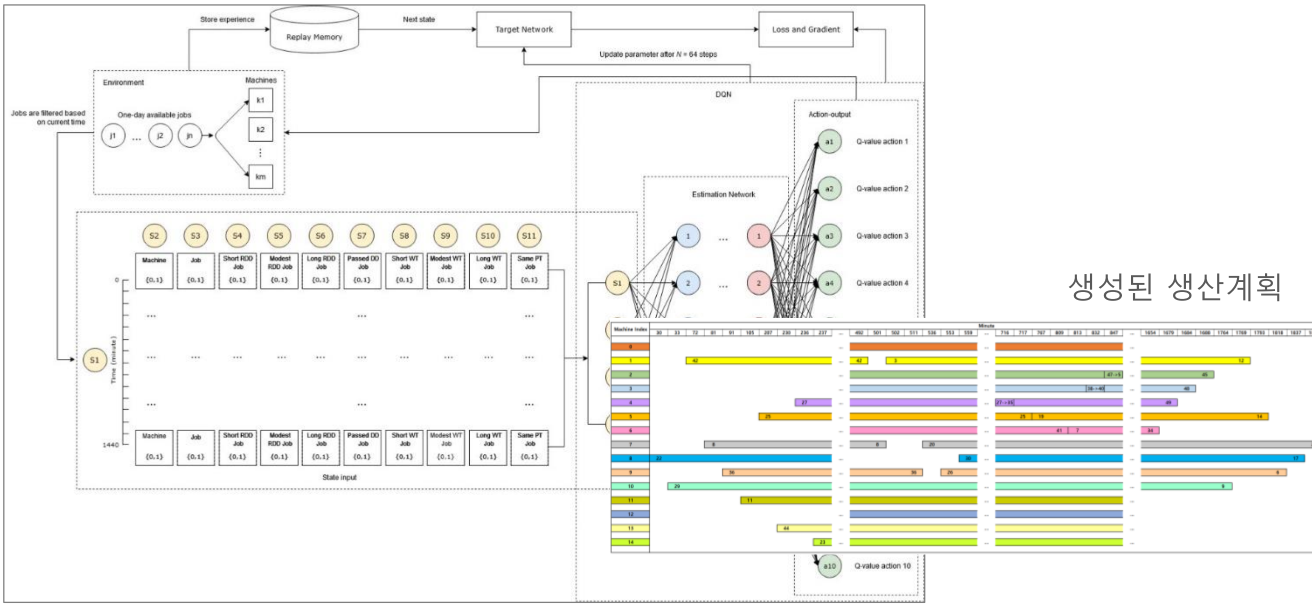
- Comparison between Deep-Neural Network and Our Approach



Deep-NN cannot perform w
ell with categorical data !

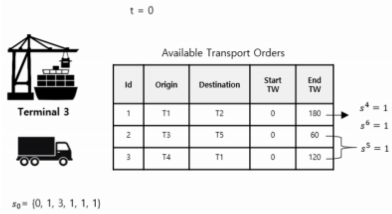
생산의사결정

- 인공지능을 활용한 병목 작업의 생산계획 수립



생성된 생산계획

생산계획에서 강화학습의 성능



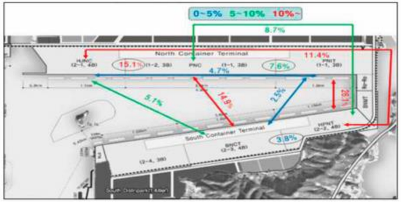


Table 7. Parameter abbreviations.

Parameters	Abbreviation
Average Computational Time (in seconds)	Avg CT
Best Computational Time (in seconds)	Best CT
Average Total Cost (in $)	Avg TC
Minimum Total Cost (in $)	Min TC
Average Empty Truck Trip Cost (in $)	Avg ETTC
Minimum Empty Truck Trip Cost (in $)	Min ETTC

Table 8. Performance comparison between DQN and SA.

	DQN						SA					
DID	Min TC	Avg TC	Min ETTC	Avg ETTC	Min CT	Avg CT	Min TC	Avg TC	Min ETTC	Avg ETTC	Best CT	Avg CT
DC1-35	291.6	310.77	84.13	103.3	32.67	56.59	316.66	341.58	109.2	128.01	23.68	51.42
DC1-89	790.66	828.03	263.2	299.53	108.41	148.4	860.26	905.4	332.79	346.44	101.92	134.86
DC2-116	1054.66	1096.02	367.99	409.35	25.05	54.57	1011.06	1052.59	324.39	365.92	118.93	157.14
DC2-173	1619.73	1660.12	594.26	633.18	91.53	146.05	1722.93	1819.7	684.13	706.85	167.43	223.91
DC3-285	2720	2787.11	1032	1099.11	189.73	315.13	2707	2746.62	1019.06	1058.62	245.87	386.54

Table 9. Performance comparison between DQN and TS.

	DQN						TS					
DID	Min TC	Avg TC	Min ETTC	Avg ETTC	Min CT	Avg CT	Min TC	Avg TC	Min ETTC	Avg ETTC	Best CT	Avg CT
DC1-35	291.6	310.77	84.13	103.3	32.67	56.59	305.2	306.29	97.73	98.82	24.14	53.44
DC1-89	790.66	828.03	263.2	299.53	108.41	148.4	845.86	849.59	318.39	322.12	104.6	138.28
DC2-116	1054.66	1096.02	367.99	409.35	25.05	54.57	975.73	984.23	289.06	297.56	125.34	158.36
DC2-173	1619.73	1660.12	594.26	633.18	91.53	146.05	1687.59	1693.17	662.13	667.65	185.53	231.18
DC3-285	2720	2787.11	1032	1099.11	189.73	315.13	2649.46	2667.45	961.46	979.45	249.68	390.58


Overhead Hoist Transport (OHT) – 반도체 공장의 자동 물류 시스템
Laser sensors
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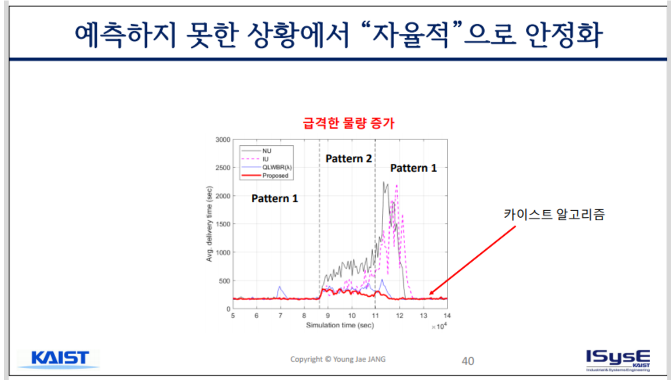
예측하지 못한 상황에서 "자율적"으로 안정화
급격한 물량 증가
Pattern 1
Pattern 2
Pattern 1
카이스트 알고리즘
Avg. delivery time (sec)
Simulation time (sec)
KAIST
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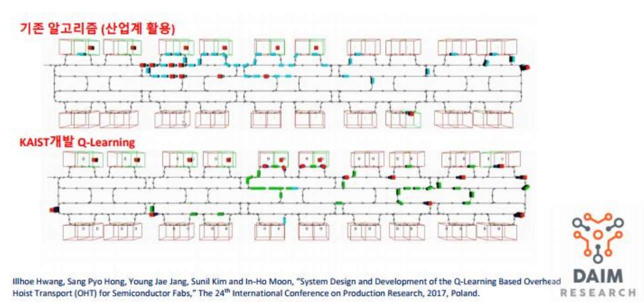
기존 알고리즘 (산업계 활용)
KAIST개발 Q-Learning
Illhoe Hwang, Sang Pyo Hong, Young Jae Jang, Sunil Kim and In-Ho Moon, "System Design and Development of the Q-Learning Based Overhead Hoist Transport (OHT) for Semiconductor Fabs," The 24th International Conference on Production Research, 2017, Poland.
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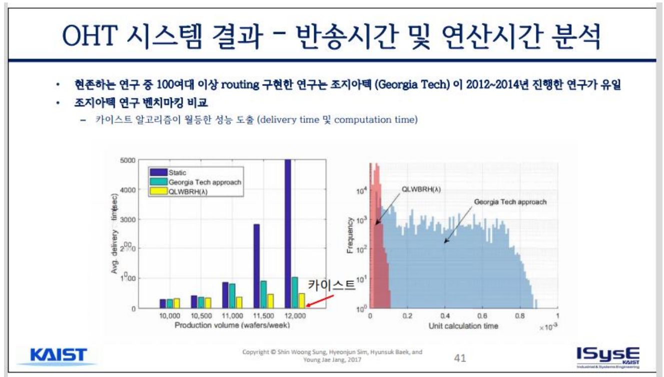
OHT 시스템 결과 – 반송시간 및 연산시간 분석
• 현존하는 연구 중 100여대 이상 routing 구현한 연구는 조지아텍 (Georgia Tech) 이 2012~2014년 진행한 연구가 유일
• 조지아텍 연구 벤치마킹 비교
– 카이스트 알고리즘이 월등한 성능 도출 (delivery time 및 computation time)
Static
Georgia Tech approach
QLWBRH(λ)
카이스트
Production volume (wafers/week)
Unit calculation time
Frequency
Georgia Tech approach
KAIST
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Digital twin + Machine Learning