





NIST Workshop

PHM frontiers in Korean manufacturing – success episodes and issues

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Seoul National University

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* PHM: Prognostics and Health Management

Part I

Smart Factory in Korea

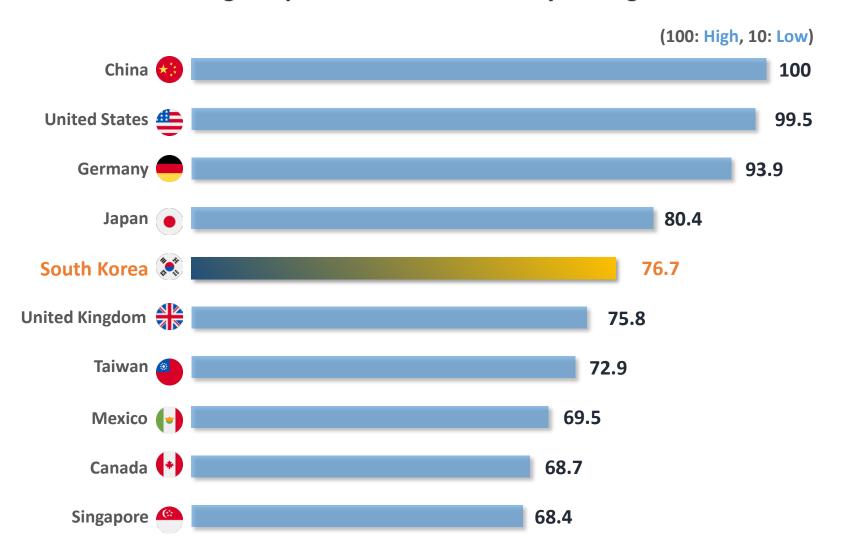








Global Manufacturing Competitiveness Index: Country rankings



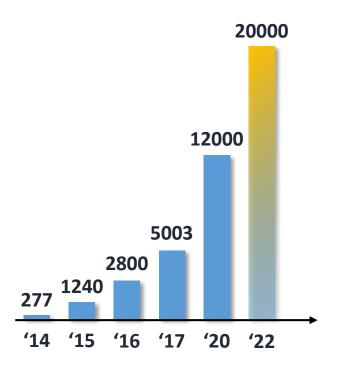
Ref: Delotte Touche Limited and US Council on Competitiveness, "2016 Global Manufacturing Competitiveness Index"







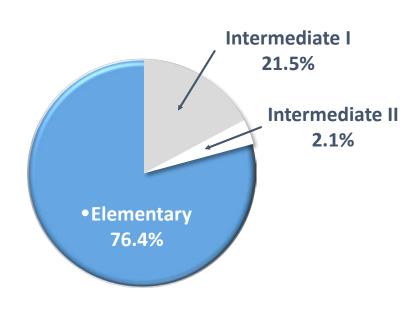
Korea Smart Factory Foundation (KOSF) Newly Launched in 2014



<Number of smart factories
supported by the KOST Program>

Number: 18 times from '14 to '17

• Level: Elementary (76.4%)



<The level of smart factories in domestic companies>

- Elementary: ERP with data acqn.
- Intermediate I: RT equipment data acqn.
- Intermediate II: RT decision making and control

Ref: '18.04 MOTIE Smart Factory Korea Foundation "2017 Successful Episodes of Smart Factory"

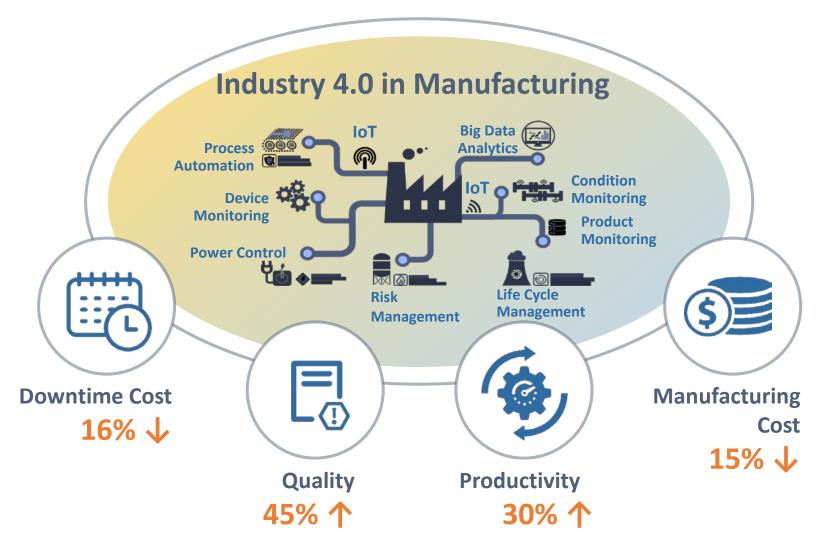






Improvement of Overall Manufacturing Capability

(2800 companies with smart factory, Dec 2017)



Ref: S&T Market Report Vol. 56 2018.02 Smart Factory Industry and Market Trend

Part II

PHM* Discipline and Activity







Sensing Solution



Reasoning Solution







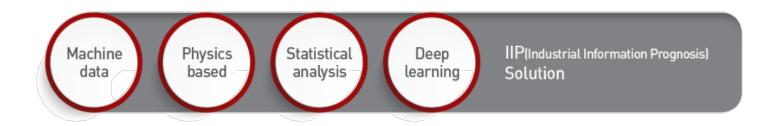


PHM Architecture









Awards



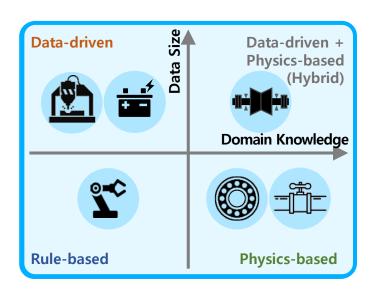
"Five times winner of Global PHM Data Challenges over Various Industrial Sectors"







Standard PHM Approaches



6 Core Assets in Manufacturing

Driving

Power Trans.

Power & Energy







Machining

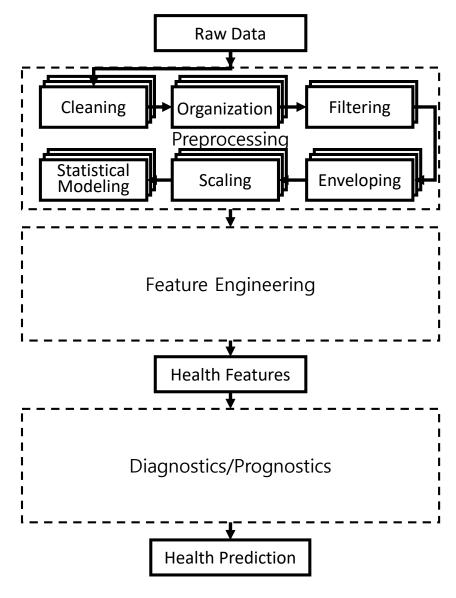
Hydrosystem **Electrical & Electronics**







Standard PHM Procedure









Standard Architecture & MDP* Table for PHM

	Exercising Standardization of Prognostics and Health Management (PHM) for Manufacturing Industry										
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	Failure	Measurement parameters								
Module	components	Vibration	Thermography	Oil Analysis	Process Parameter	Performance	Acoustic Monitoring	Electrica Monitorin		
	Power supply	D	P	D				D		
Power module	Transformer	D	-	M	-	-	М	М		
module	Energy storage system		М					М		
Hydraulic	Cylinder	Р	М	M			Р			
module	Valve	D	Р		D	М	М			
	PLC							D		
Control	Inverter	-	D		-	-		D		
module	Switch	-	-	-	-	-	-	D		
	Cable	-			-	D	D	D		
	Motor	М	М	-	М	M	D	М		
Drive module	LM Guide	D			-		D	-		
modele	Hydraulic supply	М	М	M	М	М				
	Reducer	М		M		М	D	D		
Transmissio	Ball screw	D	D		D			D		
n	Chain & Belt	Р					Р			
Module	Gear	М		М	-	D	D	D		
	Bearing	М	М	М	-	-	М	D		
Machinig	Mechanical tool	М	-	-	М	М	D	D		
module	Electrical tool				-			-		



Standard Architecture



Brochure (w/ MDP table)

*M: Mature D: Developing P: Promising

http://onepredict.com/blog/newsView.do

Part III

Successful PHM Episodes



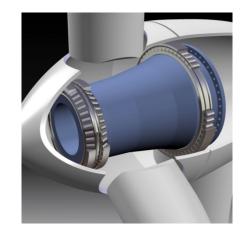






Industrial Bearing

: Rolling-Element Bearing











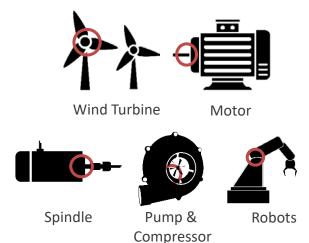








Industrial Bearings (custom order)



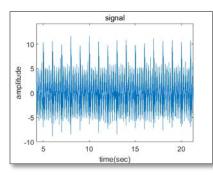
1. Sensing



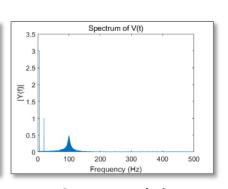


ISO 10816-1 (Vibration measured on Non-Rotating Parts)

2. Analysis

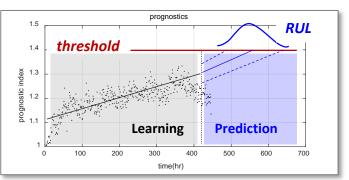


Waveform analysis



Spectrum analysis Envelope spectrum & Feature extraction

3. Diagnosis & Prognosis



Prognostic index & RUL Prediction

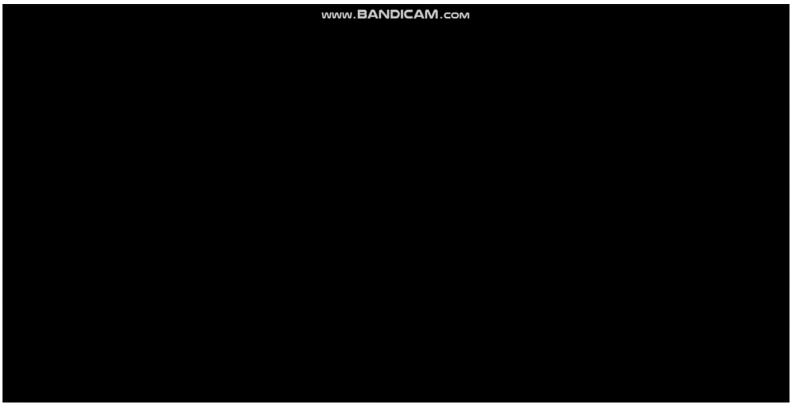








GuardiOne Bearing (Monitoring)



Real-time Monitoring of Color Image of Health Trend Monitoring **Health Condition**

Condition

of Health Condition

Remaining Life **Trend Monitoring**

"First-ever Commercial Solution for Bearing RUL Prediction"

2018-04-13

Steam/Gas Turbine w/ Journal Bearing (Data-driven, Deep Learning)







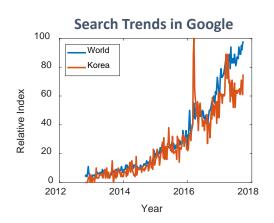


Deep Learning

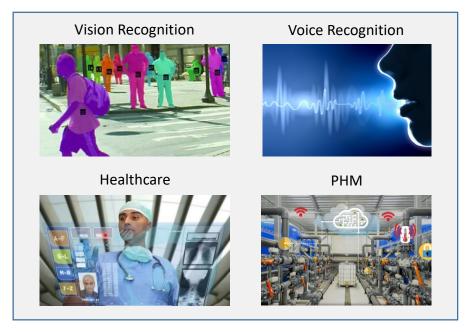
Autonomous machine learning algorithms to extract data features through abstraction of massive data sets

Popularity of Deep Learning

- Improved computing power
- Enlarged data size
- Advanced DL techniques



Applications of Deep Learning



^{*}R. Zhao et al. (2016), IEEE Tran. Neural Networks and Learning Systems (Submitted); K. Fragkiadaki (2012) Computer Vision-ECCV; Q. V. Le (2012) ICML







Data-driven Approach for Feature Learning¹⁾

Data	Feature	Feature	Feature
Acquisition	Extraction	Selection	Learning

	Domain Knowledge Based	Deep Learning Based	
Domain Knowledge	Required	Not Required	
System Dependency	Dependent	Independent	
Feature Representation	Shallow	Deep	
Big Data Learning	Over-fitted Model	Well-fitted Model	

Deep Learning Based Fault Diagnosis²⁾

Data Acquisition



Autonomous Feature Engineering by DL

DL Type	Input Data Type	Input Data Labels	Others
DBN	n/a	Unsupervised	Break through in deep learning (2006)
CNN	Vision Data (Images)	Supervised	Parameter sharing, local connectivity
RNN	Sequential Data (Speech)	Supervised	Storing sequential information
AE	n/a	Unsupervised	Representation learning, dimension reduction

^{*}H. Oh et al. (2017), IEEE Tran. Industrial Electronics

^{**} R. Zhao et al. (2016), IEEE Tran. Neural Networks and Learning Systems (Submitted)

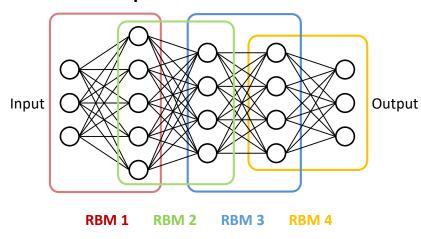




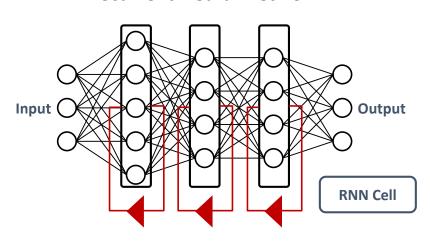


Deep Learning Algorithms¹⁾

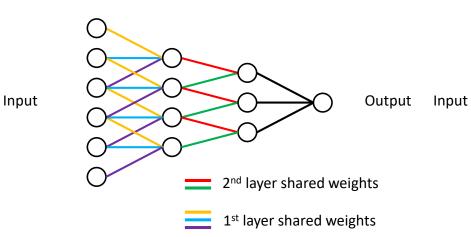
Deep Belief Network



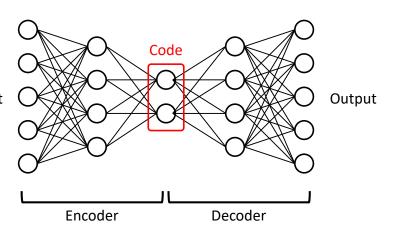
Recurrent Neural Network



Convolutional Neural Network



Auto Encoder



^{*}THE ASIMOV INSTITUTE (http://www.asimovinstitute.org)

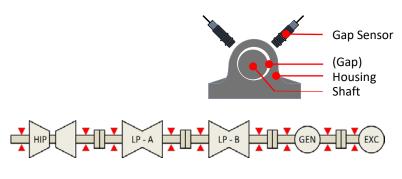






GuardiOne Turbine-Deep

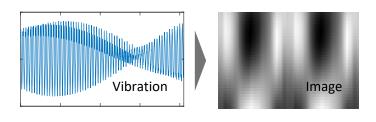
1. Sensing



Vibration Data Acquisition

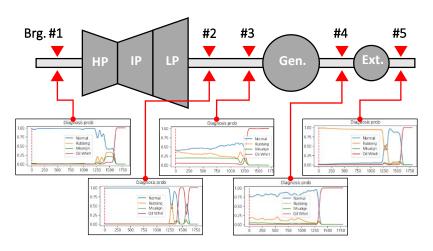
2. Analysis

Omni-directional Regeneration (ODR)



Vib-Imaging Technique

3. Scale-free Turbine Prognostics (Fully validated, 92% prediction accuracy)

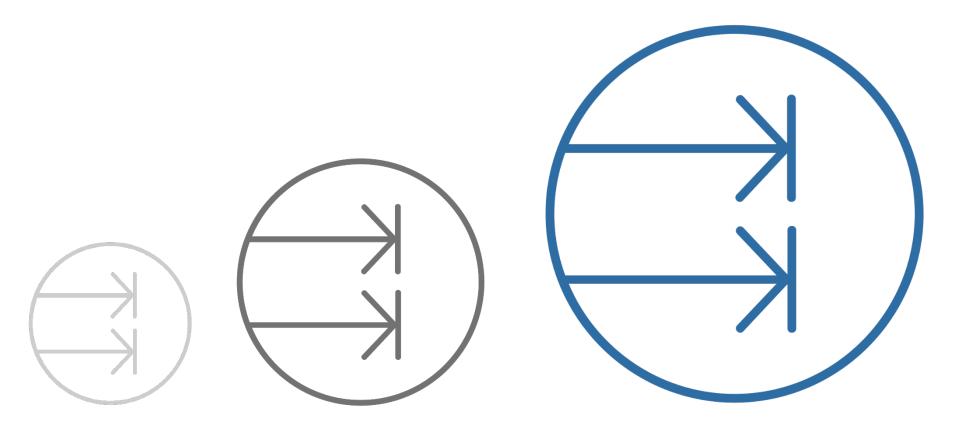


Fa	ault Log			Deep	Learnin	g Result	
#	Status		#	Norm.	Rubb.	Misalign.	Oil Whirl
#1	Normal		#1	0.975	0.010	0.014	0.006
#2	Normal		#2	0.991	0.005	0.004	0.000
#3	Normal	VS.	#3	0.482	0.288	0.186	0.042
#4	Normal		#4	0.828	0.135	0.034	0.003
#5	Rubbing		#5	0.037	0.958	0.005	0.001

2018-04-13

Part IV

Closing Remarks

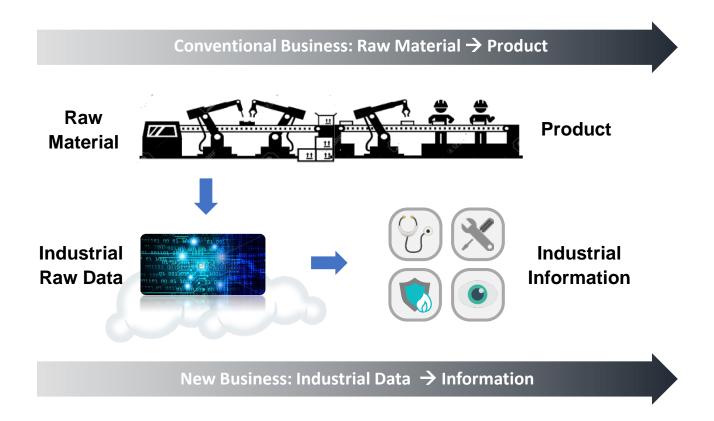








Industrial Information Prognosis (IIP)



"Industrial Information is the one with industrial value, which includes availability, quality, productivity, energy efficiency, safety, etc."

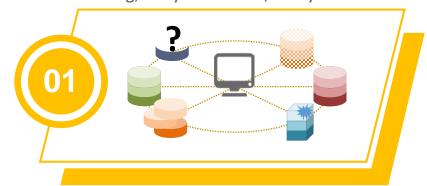






Data Quality

Missing, Unsynchronized, Noisy Data



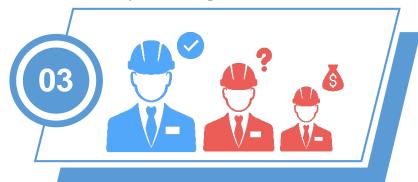
Lack of Labeled Data

Class Imbalance, Labeling Quality



Lack of Resources

PHM Experts, Budgets



Cyber Security & Data Ownership

Protection of Cloud Network Information



THANK YOU FOR LISTENING

ANY QUESTION?