26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

Conceptual Design of Smart Manufacturing Execution System Based on Systems Engineering

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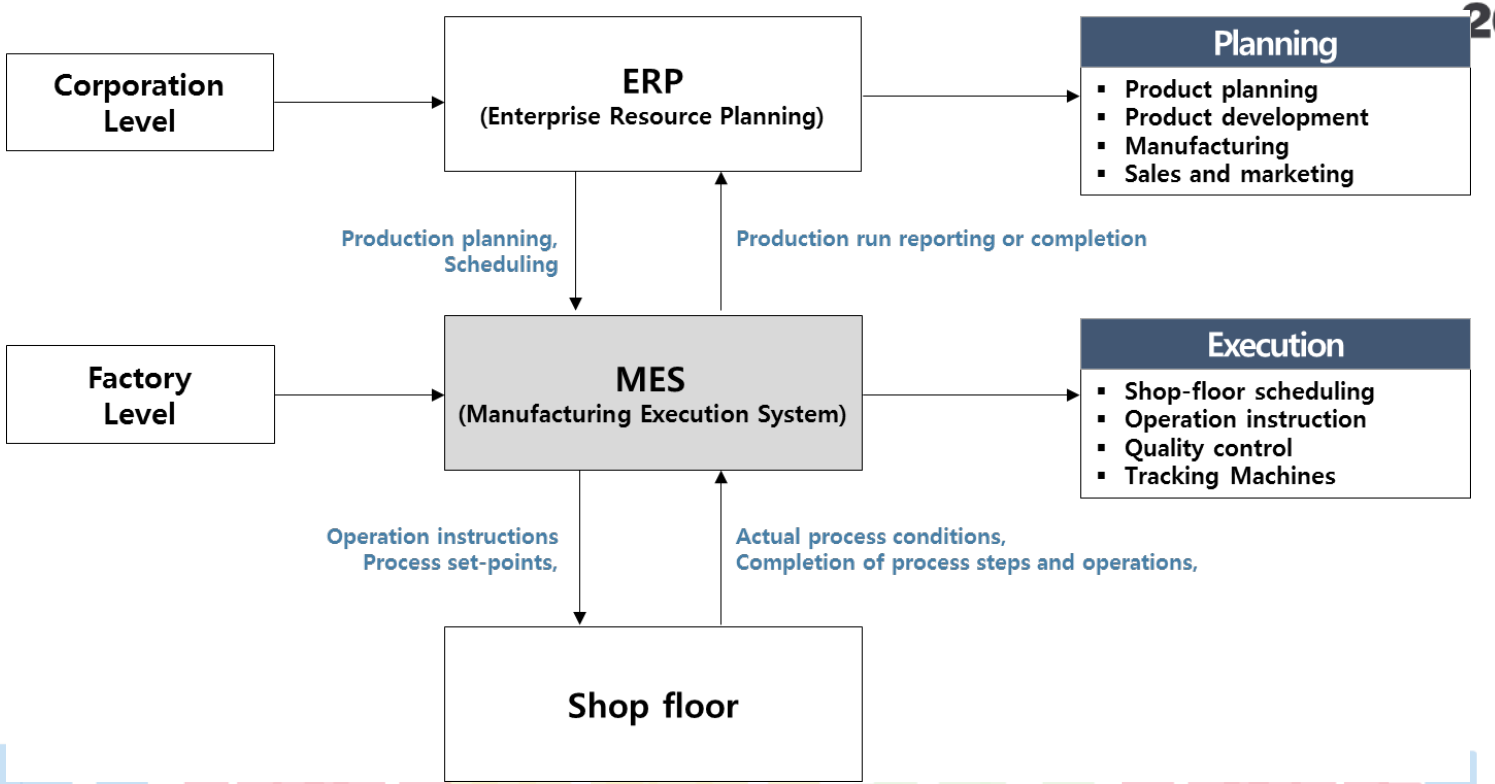
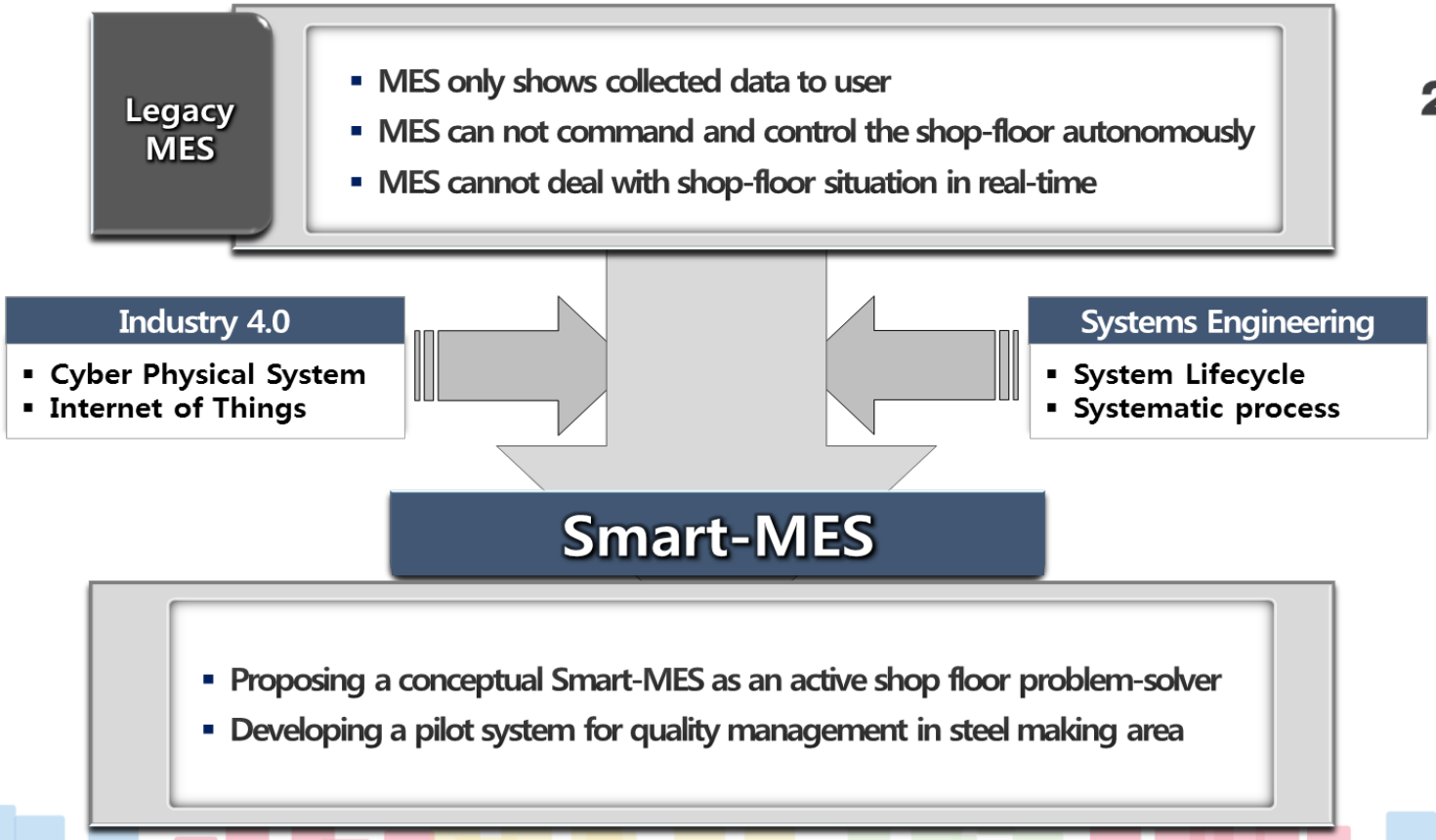
Introduction

- **MES's roles in making productions**



Introduction



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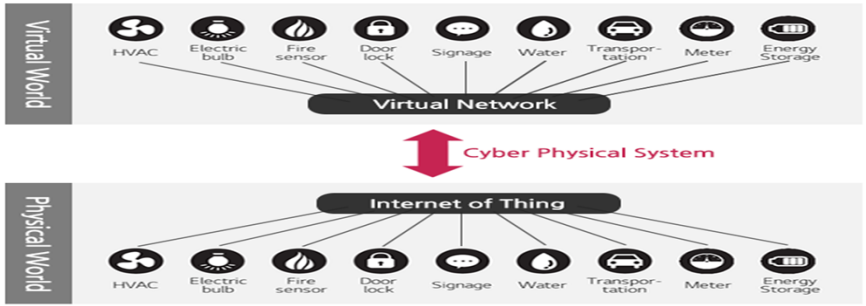
Industry 4.0

- **Industry 4.0**
  - A strategic initiative of German government
  - A part of the “High-Tech Strategy 2020 Action plan”
- **Industry 4.0 and 4th Industrial Revolution**

			
1st	2nd	3rd	4th
Mechanization	Electricity	Information Technology	IoT, CPS

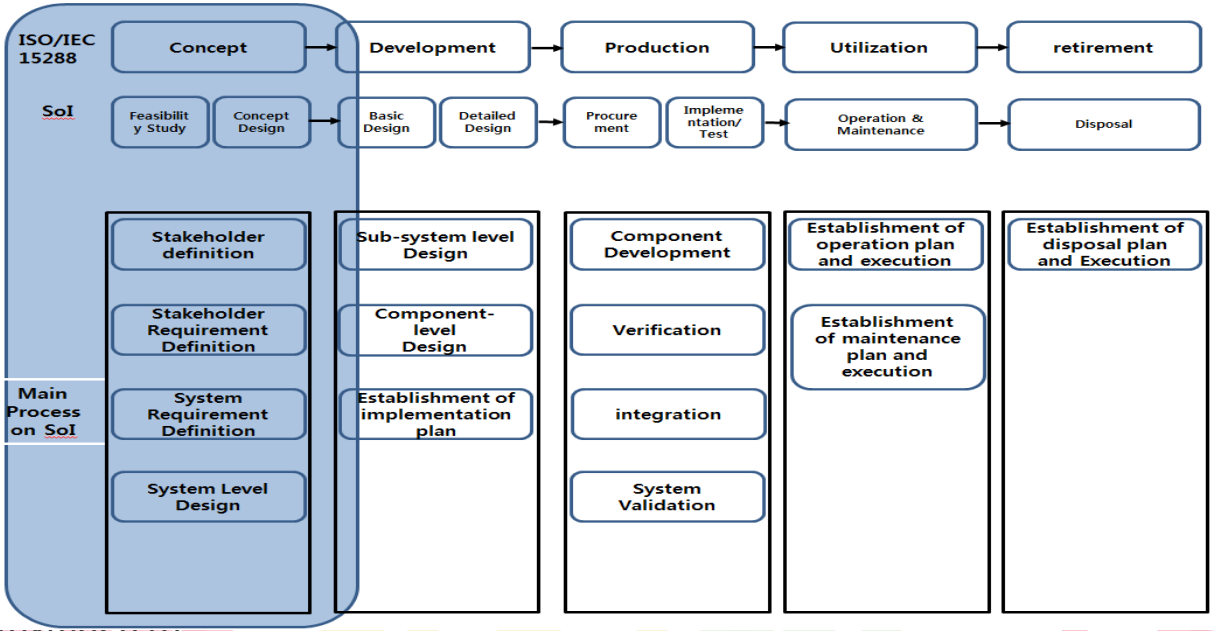
- **CPS and IoT**



- Making Flexible Manufacturing Environment
- Supporting tightly controlled and on-demand services

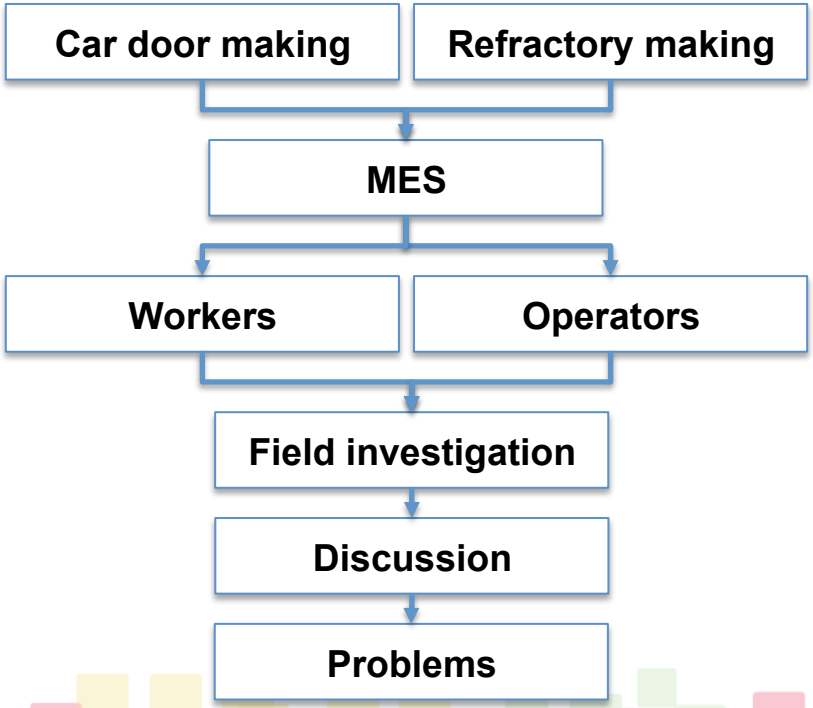
Systems Engineering

- **Smart MES and SE**
  - Supporting systematic development process
  - Organizing various requirement from stakeholders and reflecting them into system configuration
- **SE technical process of system of interest and its life cycle**



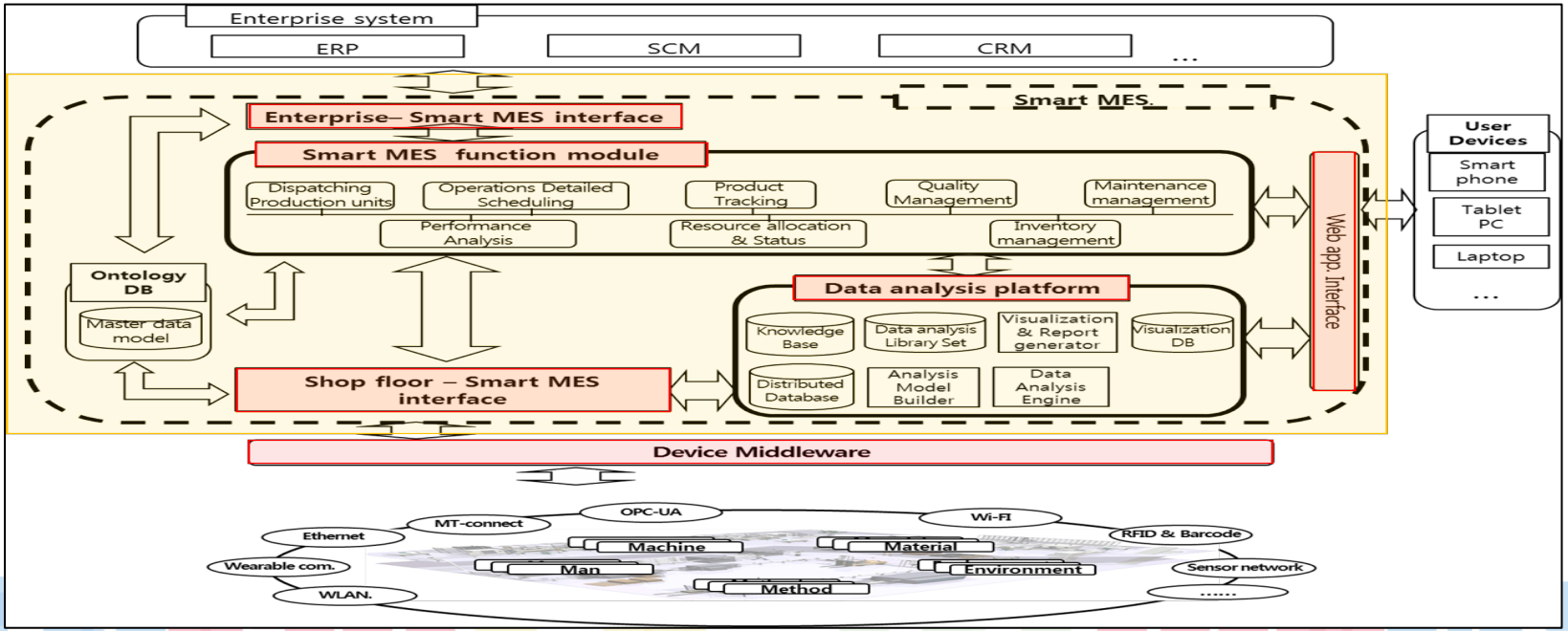
Interview

- **In order to identify problems of legacy MES**
  - Focusing on data flow and control between legacy MES and shop floor



Architecture for Smart-MES

- **Architecture for Smart-MES**
  - Consisting of six main components
    - Enterprise-Smart MES interface, Smart-MES function module, Data analysis platform, shop floor-Sm art MES interface, Device Middleware, and Web application interface



Architecture for Smart-MES

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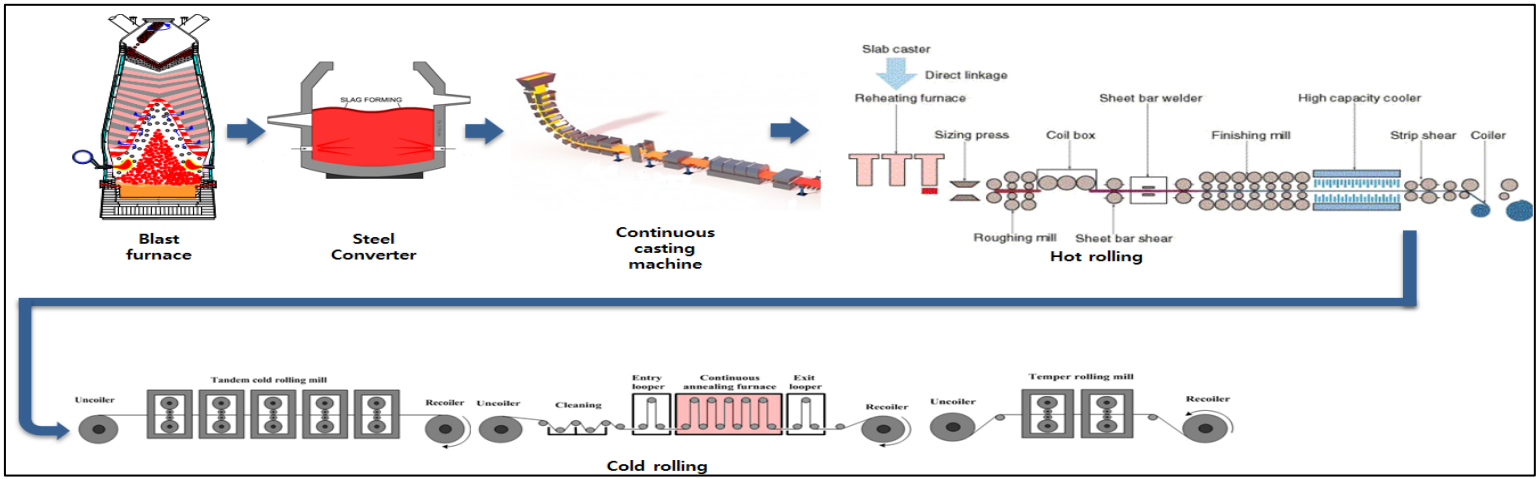
- **Enterprise-Smart MES interface**
  - Playing a role as an adapter between enterprise system and Smart-MES
- **Shop floor-Smart MES interface**
  - Transforming different data type of shop floor into data type of smart-MES
- **Device Middleware**
  - Supporting s various shop floor communication protocols and delivering data to Smart MES
- **Data analysis platform**
  - Performing data storage, data analysis, data visualization, knowledge extraction, etc.
- **Smart-MES function module**
  - Using data analysis result to determine actions properly to take in the shop floor
- **Web application interface**
  - Supporting various user device protocol such as smart phone, tablet PC, laptop, etc.

Case study: cold rolling process in steel mill

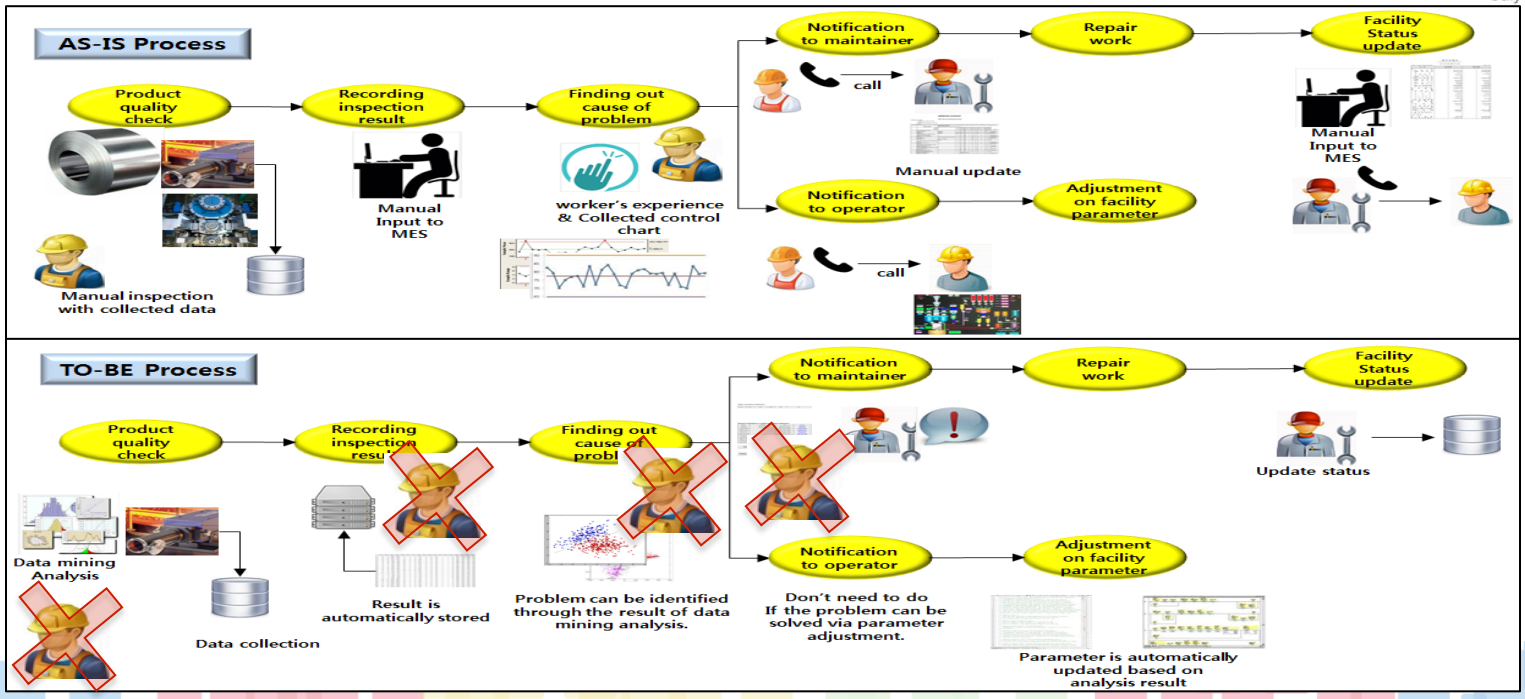
- **Company A**
  - Integrated steel mill which makes steel and iron product from raw ore and other materials with blast furnace, steel converter, continuous casting, rolling mill
- **Iron and steel making process**



- **Sol**
  - Quality management of cold rolling process in steel mill

Case study: cold rolling process in steel mill

- **A pilot Smart-MES system for quality management as a To-Be model**
  - Describing a situation that Smart MES is applied
  - In comparison with current manufacturing environment



Case study: cold rolling process in steel mill

- **Data Collection**
  - 1,941 data sets which are generated from quality control stage in cold rolling process
  - Information concerning product name, product type, product specifications, product condition, defective type, etc.
  - Pastry, Z-Scratch, K-Scratch, Stains, Dirtiness, Bumps, Others

28 data items

1941 Data sets

Faults.NNA - 메모장

파일(F) 편집(E) 서식(O) 보기(V) 도움말(H)

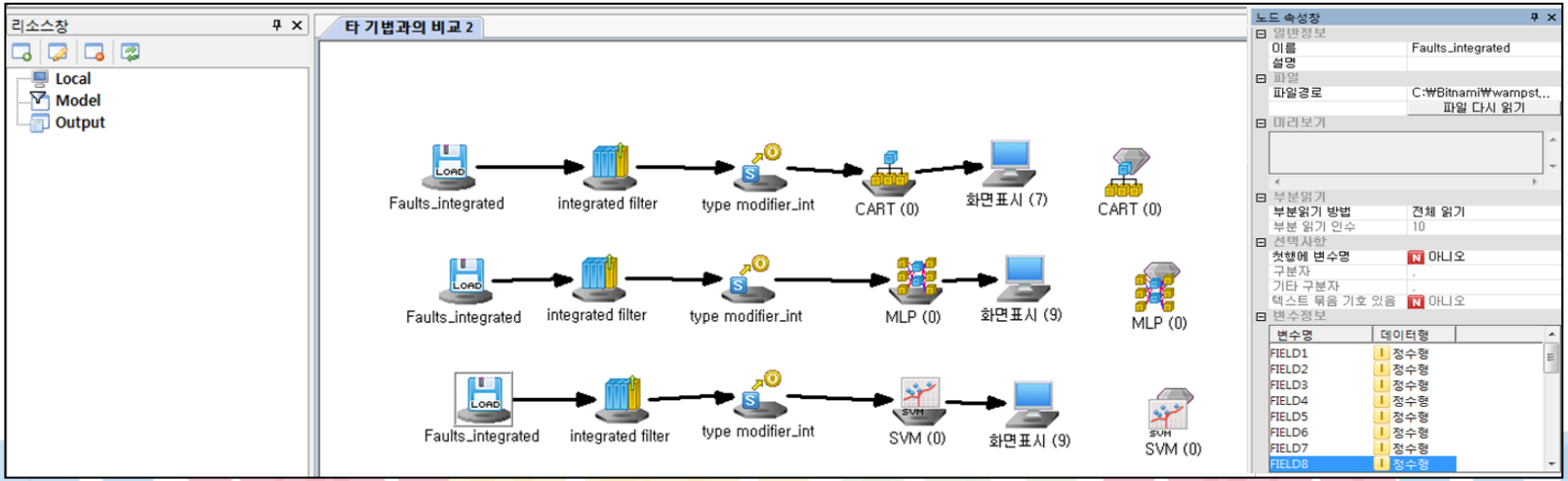
42	50	270900	270944	267	17	44	24220	76	108	1687	1	0	80	0.0498	0.2415	0.1818	0.0047	0.4706	1	1	2.4265	0.9031	1.6435	0.8182	-0.2913	0.5822	1	0
645	651	2538079	2538108	108	10	30	11397	84	123	1687	1	0	80	0.7647	0.3793	0.2069	0.0036	0.6	0.9667	1	2.0334	0.7782	1.4624	0.7931	-0.1756	0.2984	1	0
829	835	1553913	1553931	71	8	19	7972	99	125	1623	1	0	100	0.971	0.3426	0.3333	0.0037	0.75	0.9474	1	1.8513	0.7782	1.2553	0.6667	-0.1228	0.215	1	0
853	860	369370	369415	176	13	45	18996	99	126	1353	0	1	290	0.7287	0.4413	0.1556	0.0052	0.5385	1	1	2.2455	0.8451	1.6532	0.8444	-0.1568	0.5212	1	0
1289	1306	498078	498335	2409	60	260	246930	37	126	1353	0	1	185	0.0695	0.4486	0.0662	0.0126	0.2833	0.9885	1	3.3818	1.2305	2.4099	0.9338	-0.1992	1	1	0
430	441	100250	100337	630	20	87	62357	64	127	1387	0	1	40	0.62	0.3417	0.1264	0.0079	0.55	1	1	2.7993	1.0414	1.9395	0.8736	-0.2267	0.9874	1	0
413	446	138468	138883	9052	230	432	1481991	23	199	1687	0	1	150	0.4896	0.339	0.0795	0.0196	0.1435	0.9607	1	3.9567	1.5185	2.6181	0.9205	0.2791	1	1	0
190	200	210936	210956	132	11	20	20007	124	172	1687	0	1	150	0.2253	0.34	0.5	0.0059	0.9091	1	1	2.1206	1	1.301	0.5	0.1841	0.3359	1	0
330	343	429227	429253	264	15	26	29748	53	148	1687	0	1	150	0.3912	0.2189	0.5	0.0077	0.8667	1	1	2.4216	1.1139	1.415	0.5	-0.1197	0.5593	1	0
74	90	779144	779308	1506	46	167	180215	53	143	1687	0	1	150	0.0877	0.4261	0.0976	0.0095	0.3478	0.982	1	3.1778	1.2041	2.2148	0.9024	-0.0651	1	1	0
106	118	813452	813500	442	13	48	50393	76	143	1687	0	1	150	0.1257	0.2326	0.25	0.0071	0.9231	1	1	2.6454	1.0792	1.6812	0.75	-0.1093	0.8612	1	0
505	515	106604	106668	284	42	69	31062	97	119	1687	0	1	150	0.5967	0.5562	0.1563	0.0059	0.2381	0.9275	1	2.4533	1	1.8062	0.8438	-0.1455	0.9048	1	0
46	58	179258	179312	480	15	54	61966	102	158	1687	0	1	150	0.0545	0.2593	0.2222	0.0071	0.8	1	1	2.6812	1.0792	1.7324	0.7778	0.0086	0.9093	1	0
581	590	230644	230704	433	22	60	38917	62	111	1687	0	1	150	0.6888	0.1981	0.15	0.0053	0.4091	1	1	2.6365	0.9542	1.7781	0.85	-0.2978	0.8299	1	0
451	466	368143	368208	728	30	68	69258	36	133	1687	0	1	150	0.5347	0.2533	0.2308	0.0089	0.5	0.9559	1	2.8621	1.1761	1.8129	0.7692	-0.2568	0.9888	1	0
669	684	491552	491684	1097	59	133	119540	50	134	1687	0	1	150	0.7931	0.446	0.1136	0.0089	0.2542	0.9325	1	3.0402	1.1761	2.1206	0.8864	-0.1487	1	1	0
156	192	713788	714056	5044	167	282	570911	11	143	1687	0	1	150	0.1849	0.4772	0.1343	0.0213	0.2156	0.9503	1	3.7028	1.5563	2.4281	0.8657	-0.1157	1	1	0
90	104	751059	751132	552	38	76	59750	79	134	1687	0	1	150	0.1067	0.4599	0.1918	0.0083	0.3684	0.9605	1	2.7419	1.1461	1.8633	0.8082	-0.1543	0.9918	1	0
82	89	844704	844729	137	8	25	14907	92	126	1687	0	1	150	0.0972	0.2171	0.28	0.0041	0.875	1	1	2.1367	0.8451	1.3979	0.72	-0.1499	0.2998	1	0
1601	1613	21349	21376	209	15	22	24807	96	141	1682	0	1	200	0.0877	0.3549	0.4444	0.0071	0.8	1	1	2.3201	1.0792	1.4314	0.5556	-0.0722	0.5362	1	0

...

Results of Quality Check

Case study: cold rolling process in steel mill

- **Data Mining Algorithm**
  - Establishing classification models by applying separate learning algorithms for training data sets
  - Decision tree, neural network and SVM
    - ✓ The most typical mining techniques in Classification forecast domain
  - Modeling classification forecast using ECMiner software
    - ✓ ECMiner is a big data analysis solution



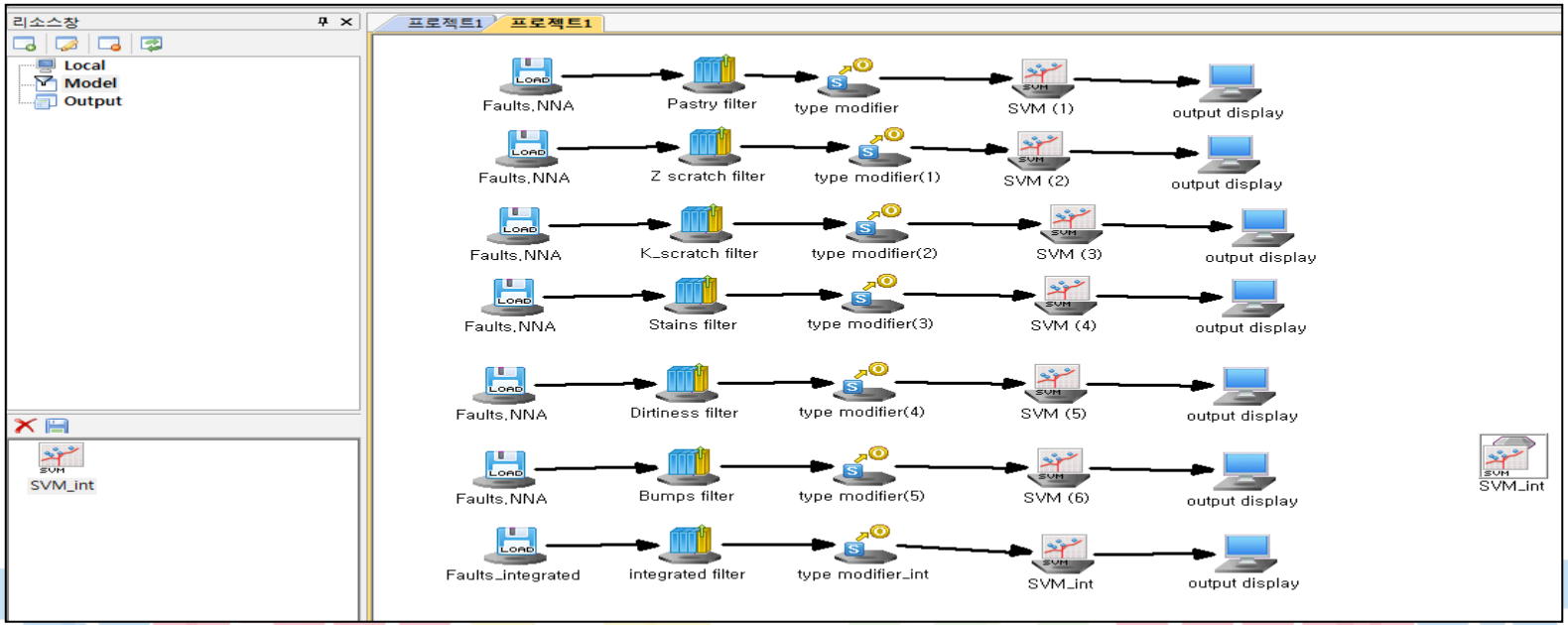
Case study: cold rolling process in steel mill

- **Data Mining Algorithm**
  - Evaluating performance of classification models such as decision tree, neural network and SVM
  - In CART learning model, average rate of classification is 67.54%
  - In MLP learning model, average rate of classification is 90.06%
  - In SVM learning model, average rate of classification is 98.35%

	CART classification and regression Trees	MLP Neural Network	SVM
Average number of classification	1,311	1,748	1,909
Average rate of classification	67.54%	90.06%	98.35%

Case study: cold rolling process in steel mill

- **Data Mining Modeling**
  - Establishing classification forecast models using SVM
  - Conducting pre-evaluation on each fault type of cold roll
  - Performing integrated analysis to distinguish the fault type of cold roll



Case study: cold rolling process in steel mill

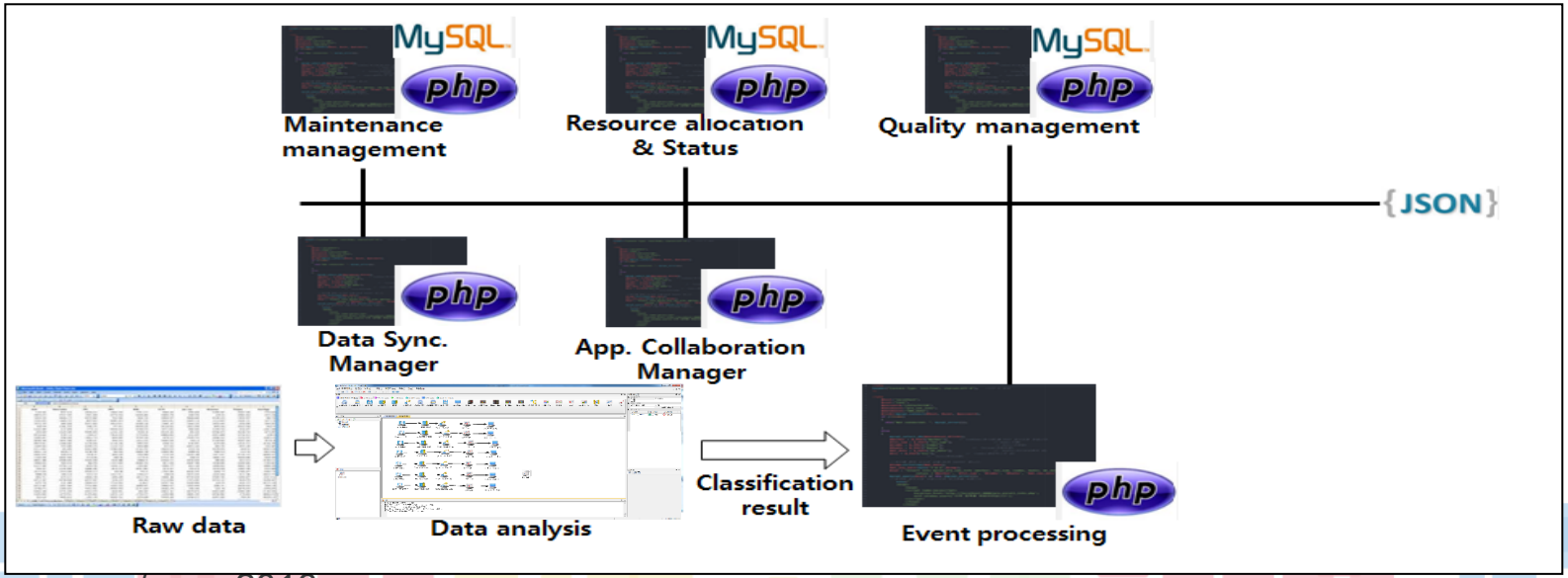
- **Data Mining Result**
  - Row with 0~6: Pastry, Z-Scratch, K-Scratch, Stains, Dirtiness, Bumps, Others
  - Column with 0~6: data mining models
  - Average number of classification: 1909
  - Average rate of classification: 98.35%

	[예측] 0	[예측] 1	[예측] 2	[예측] 3
0	158 (100,00 %)	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
1	0 (0,00 %)	190 (100,00 %)	0 (0,00 %)	0 (0,00 %)
2	0 (0,00 %)	0 (0,00 %)	391 (100,00 %)	0 (0,00 %)
3	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)	72 (100,00 %)
4	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
5	0 (0,00 %)	1 (0,25 %)	0 (0,00 %)	0 (0,00 %)
6	3 (0,45 %)	0 (0,00 %)	2 (0,30 %)	0 (0,00 %)

	[예측] 4	[예측] 5	[예측] 6
0	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
1	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
2	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
3	0 (0,00 %)	0 (0,00 %)	0 (0,00 %)
4	55 (100,00 %)	0 (0,00 %)	0 (0,00 %)
5	0 (0,00 %)	392 (97,51 %)	9 (2,24 %)
6	0 (0,00 %)	17 (2,53 %)	651 (96,73 %)

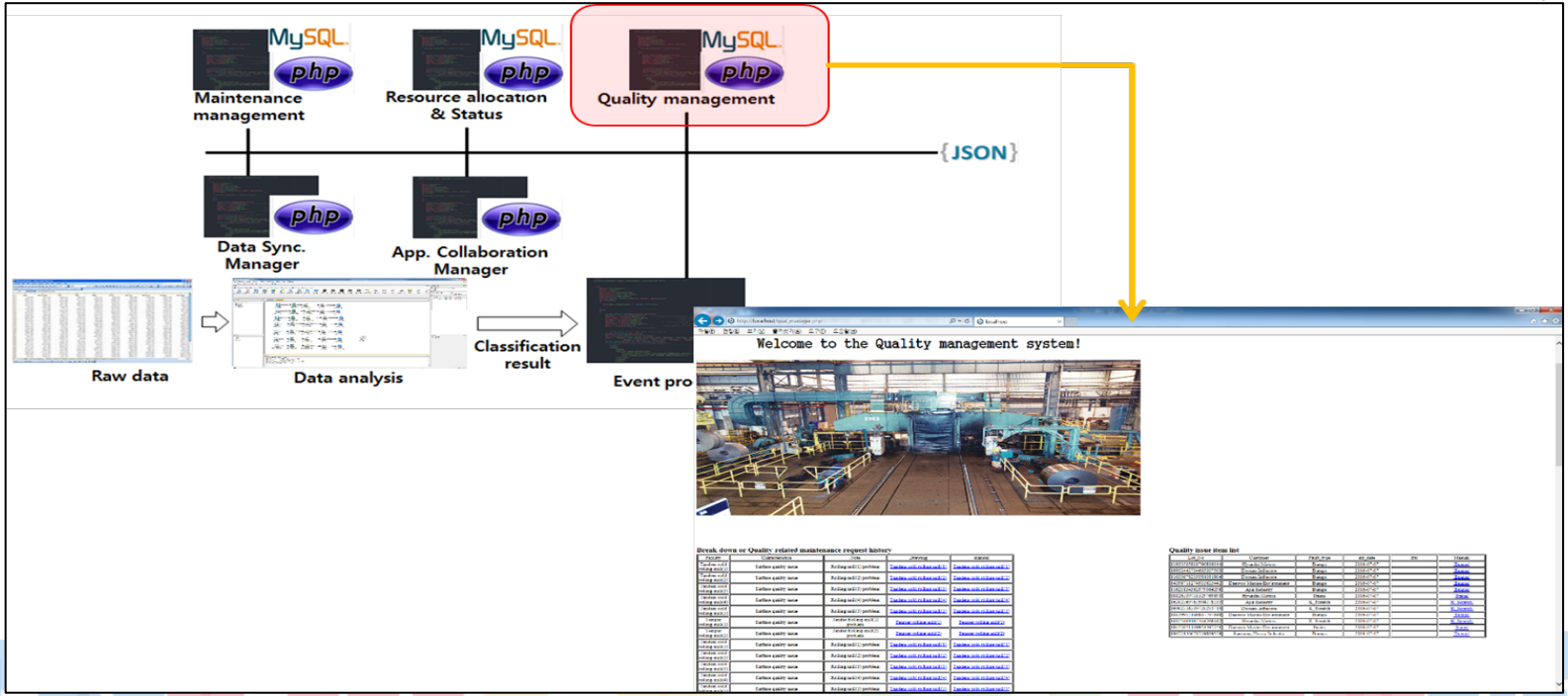
A prototype system for quality management

- **Developing Web-based prototype system for quality management using PHP, MySQL**
  - Consisting of five main components
- **Conducting quality management service**
  - Utilizing ECMiner Software as a data mining tool to analyze data



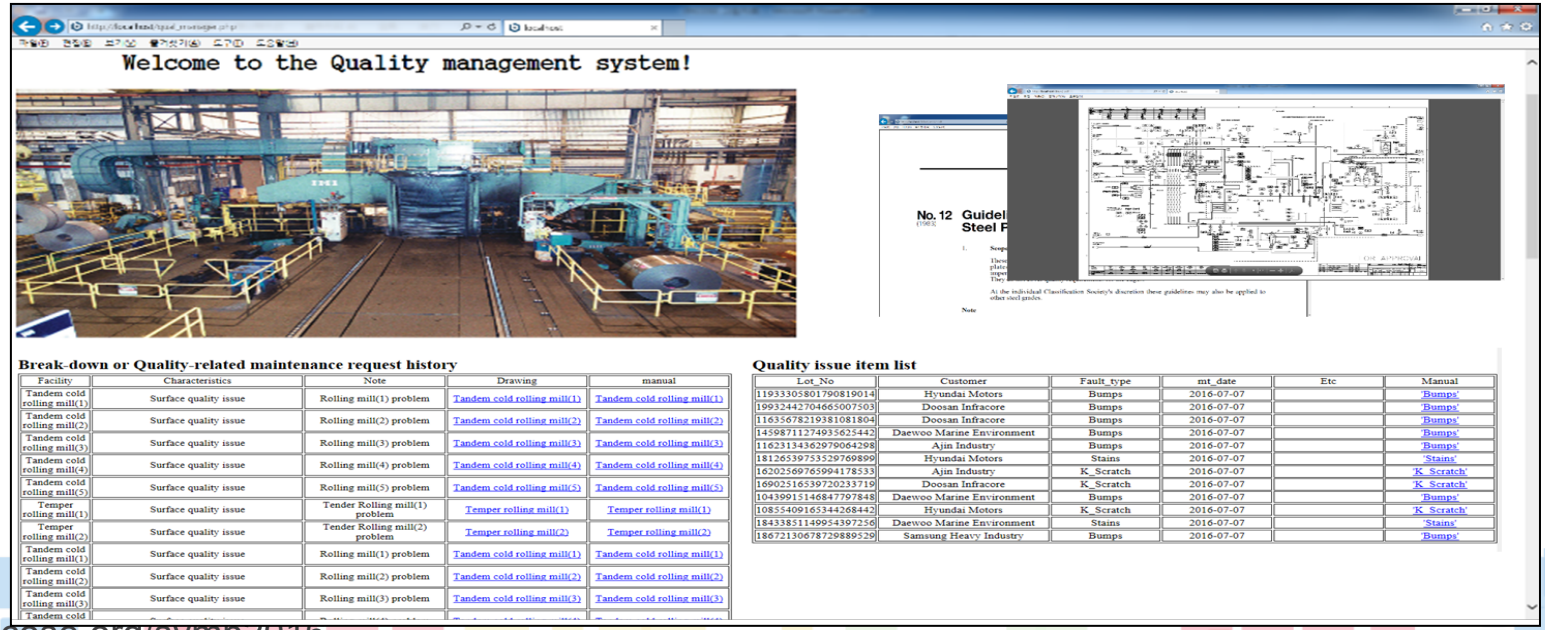
A prototype system for quality management

- **If the quality fault is related to machine breakdown**
  - Quality management application updates quality issue item list and requests maintenance



A prototype system for quality management

- **Quality management web page**
  - Quality issue item list
    - Quality management application updates fault information autonomously
  - Maintenance request history
    - When the quality issue is related to facility breakdown, this system notifies problems to maintainer in near real-time



Break-down or Quality-related maintenance request history

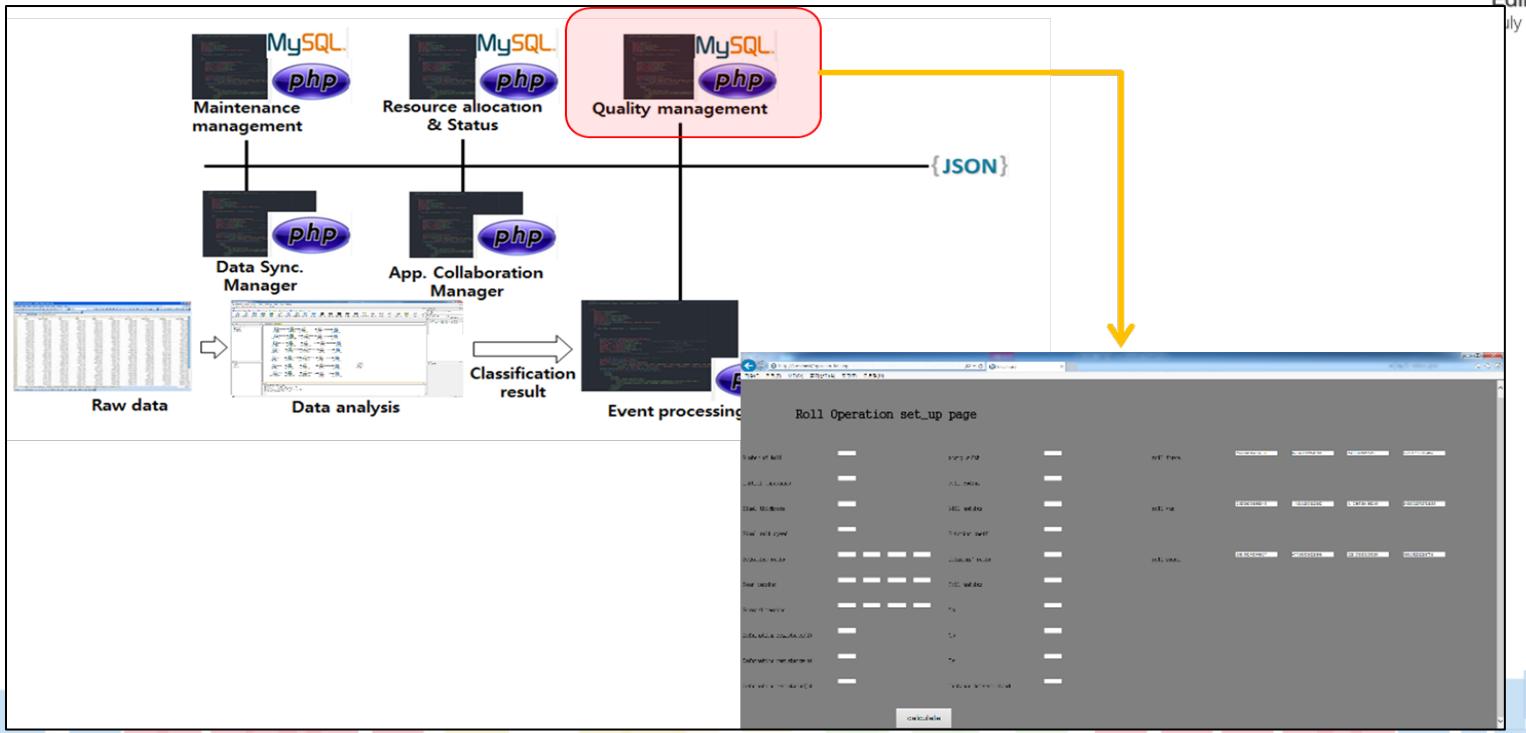
Facility	Characteristics	Note	Drawing	manual
Tandem cold rolling mill(1)	Surface quality issue	Rolling mill(1) problem	Tandem cold rolling mill(1)	Tandem cold rolling mill(1)
Tandem cold rolling mill(2)	Surface quality issue	Rolling mill(2) problem	Tandem cold rolling mill(2)	Tandem cold rolling mill(2)
Tandem cold rolling mill(3)	Surface quality issue	Rolling mill(3) problem	Tandem cold rolling mill(3)	Tandem cold rolling mill(3)
Tandem cold rolling mill(4)	Surface quality issue	Rolling mill(4) problem	Tandem cold rolling mill(4)	Tandem cold rolling mill(4)
Tandem cold rolling mill(5)	Surface quality issue	Rolling mill(5) problem	Tandem cold rolling mill(5)	Tandem cold rolling mill(5)
Temper rolling mill(1)	Surface quality issue	Tender Rolling mill(1) problem	Temper rolling mill(1)	Temper rolling mill(1)
Temper rolling mill(2)	Surface quality issue	Tender Rolling mill(2) problem	Temper rolling mill(2)	Temper rolling mill(2)
Tandem cold rolling mill(1)	Surface quality issue	Rolling mill(1) problem	Tandem cold rolling mill(1)	Tandem cold rolling mill(1)
Tandem cold rolling mill(2)	Surface quality issue	Rolling mill(2) problem	Tandem cold rolling mill(2)	Tandem cold rolling mill(2)
Tandem cold rolling mill(3)	Surface quality issue	Rolling mill(3) problem	Tandem cold rolling mill(3)	Tandem cold rolling mill(3)
Tandem cold				

Quality issue item list

Lot_No	Customer	Fault_type	mt_date	Etc	Manual
11933305801790819014	Hyundai Motors	Bumps	2016-07-07		'Bumps'
19932442704665007503	Doosan Infracore	Bumps	2016-07-07		'Bumps'
11635678219381081804	Doosan Infracore	Bumps	2016-07-07		'Bumps'
14598711274935625442	Daewoo Marine Environment	Bumps	2016-07-07		'Bumps'
11623134362979064298	Ajin Industry	Bumps	2016-07-07		'Bumps'
18126539753529769899	Hyundai Motors	Stains	2016-07-07		'Stains'
16202569765994178533	Ajin Industry	K_Scratch	2016-07-07		'K_Scratch'
16902516539720233719	Doosan Infracore	K_Scratch	2016-07-07		'K_Scratch'
10439915146847797848	Daewoo Marine Environment	Bumps	2016-07-07		'Bumps'
10855409165344268442	Hyundai Motors	K_Scratch	2016-07-07		'K_Scratch'
18433851149954397256	Daewoo Marine Environment	Stains	2016-07-07		'Stains'
18672130678729889529	Samsung Heavy Industry	Bumps	2016-07-07		'Bumps'

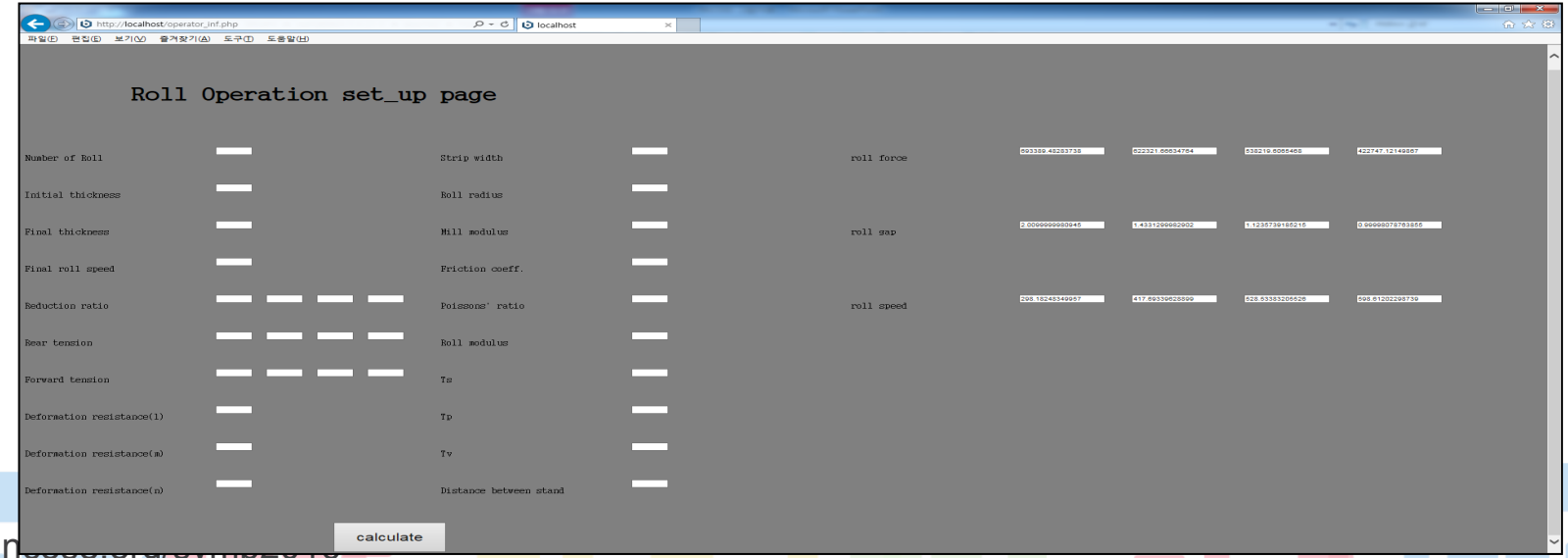
A prototype system for quality management

- **If the quality fault can be solved via parameter adjustment**
  - Quality management application updates operation parameter value automatically



A prototype system for quality management

- **Roll Operation Set-up page**
  - Key configuration settings
    - Number of roll, roll thickness, roll speed, roll radius, and strip width, and so on
  - Operation parameters
    - Roll force, roll gap, roll speed comes out in cold rolling process
  - Offering the adjustment function dynamically according to the cold roll condition



Conclusion

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- **Summary**
  - The necessity for Smart MES by pointing out lack of analysing and interpreting shop-floor data, and responding shop-floor situation
  - Proposing an conceptual design of Smart-MES based on systems engineering
  - Developing A pilot system for quality management in steel making area

- **Limitations**
  - Using 1,941 data sets and SVM to find out cause of problem
  - Depending on how much data you have

- **Further Research**
  - In order to apply smart MES technology to real field,
    The pilot system needs to be elaborated more and more