Connected Health Summer School

Artimino, Tuscany, Italy 26 -30 June 2017

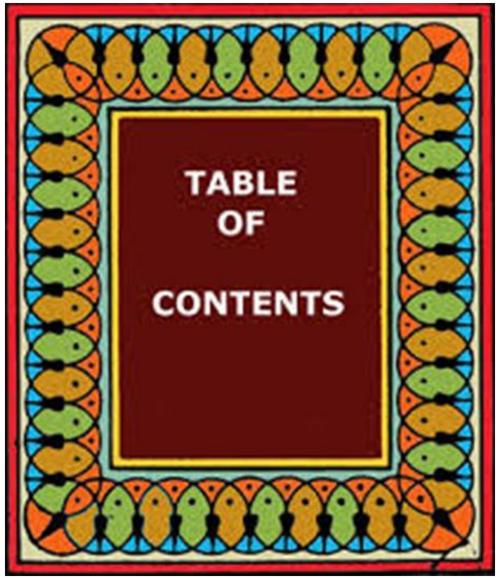
Intelligent Medical Platform

June 25th, 2017

Professor Sungyoung Lee

Kyung Hee University, Korea

Background



- Introduction to UC Lab., KHU, Korea
- Preliminary Works - Smart CDSS
- Video for Knowledge Construction
- IMP(Intelligent Medical Platform)
- Benefits & Lessons
- Video for IMP Concept

Appendix

Introduction to Ubiquitous Computing Lab, KHU, Korea

경희대학교
KYUNG HEE UNIVERSITY

[Professor Sungyoung Lee]

[Ubiquitous Computing Lab, since 1993]

UCL *Ubiquitous Computing Laboratory*
Kyung Hee University, Korea

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College of Electronics and Information,
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sylee@oslab.khu.ac.kr
http://uclab.khu.ac.kr

Authored/coauthored more than 500 technical articles (190 of which are published in archival journals)

Current Members (25)
2 Post Doctorate Researchers
14 PhD Students
6 MS Students
3 Undergraduate Students

Major Projects

Smart CDSS
Clinical Decision Support System
2006- 2014

MINING MINDS
2014- 2018

INTELLIGENT MEDICAL PLATFORM
2017-2023

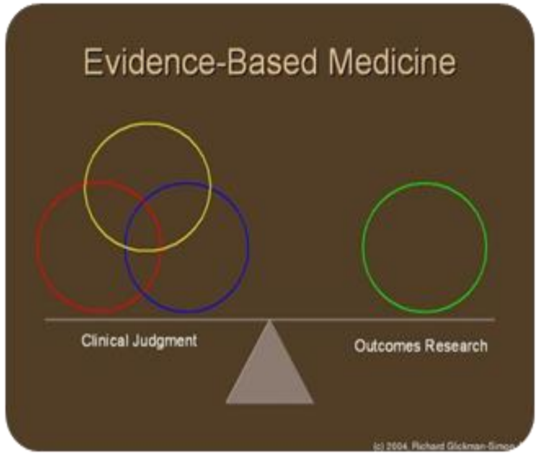
Introduction to UC Lab: Research Interests

Machine Learning	Context Aware Computing	Ontology Engineering and Matching
Interoperability	Clinical Decision Support System (CDSS)	Knowledge Authoring Tool Development
Big Data	Activity and Emotion Recognition	uHealthcare
Security and Privacy	**User Experience**	Cloud Computing

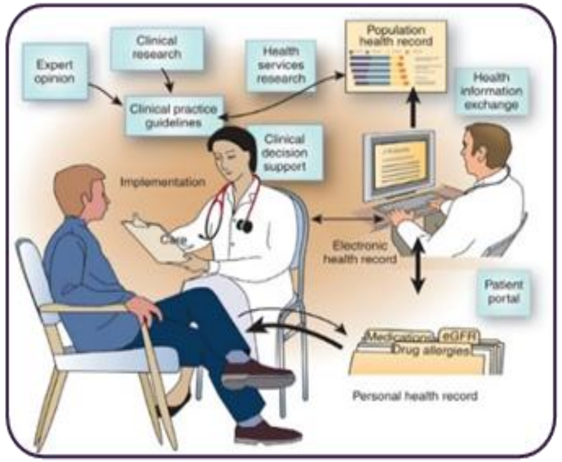
Smart CDSS

What is CDSS (Clinical Decision Support Systems) & Why CDSS?

Social Needs	Solutions	Expected Impacts
Quality of Medical Services	Smart CDSS	Improve quality of healthcare delivery
Reduce Medical Cost		Save Medicare cost
Efficiency & Safety		Reduce medical malpractices



Decision Making

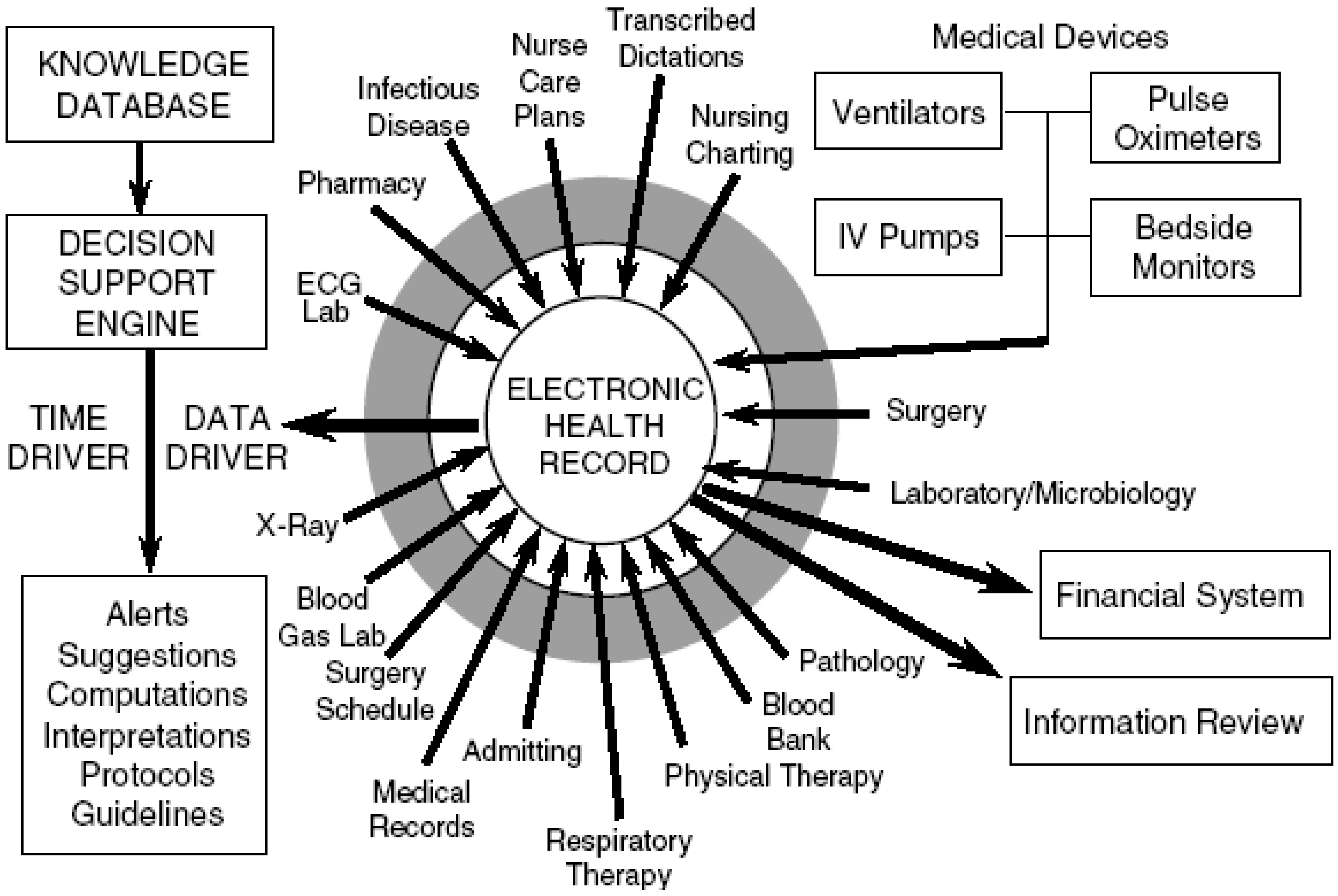


Clinical Practice Guidelines

Efficiency of healthcare delivery

Patient Safety

CDSS Architecture in General



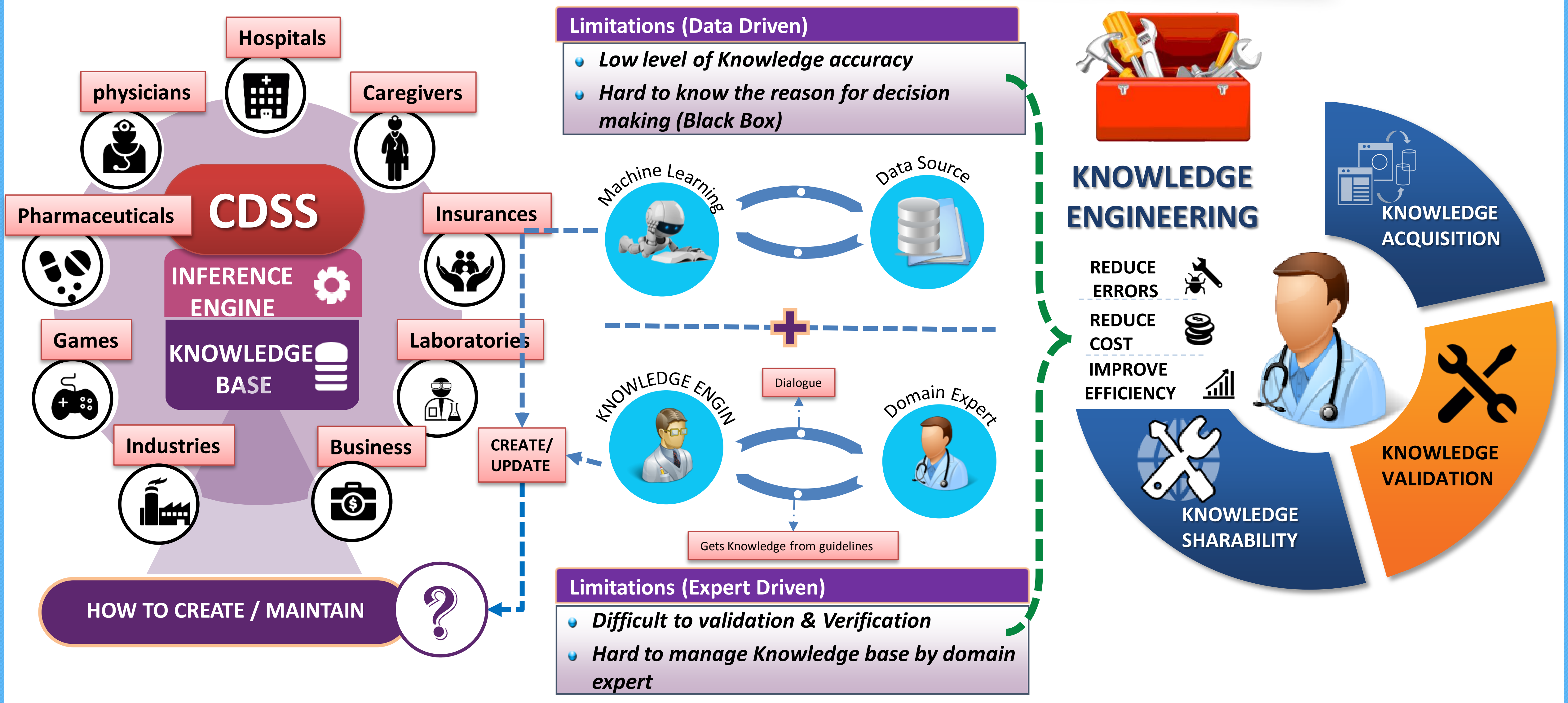
Requirements of CDSS Knowledge base

Requirements of Knowledge Construction

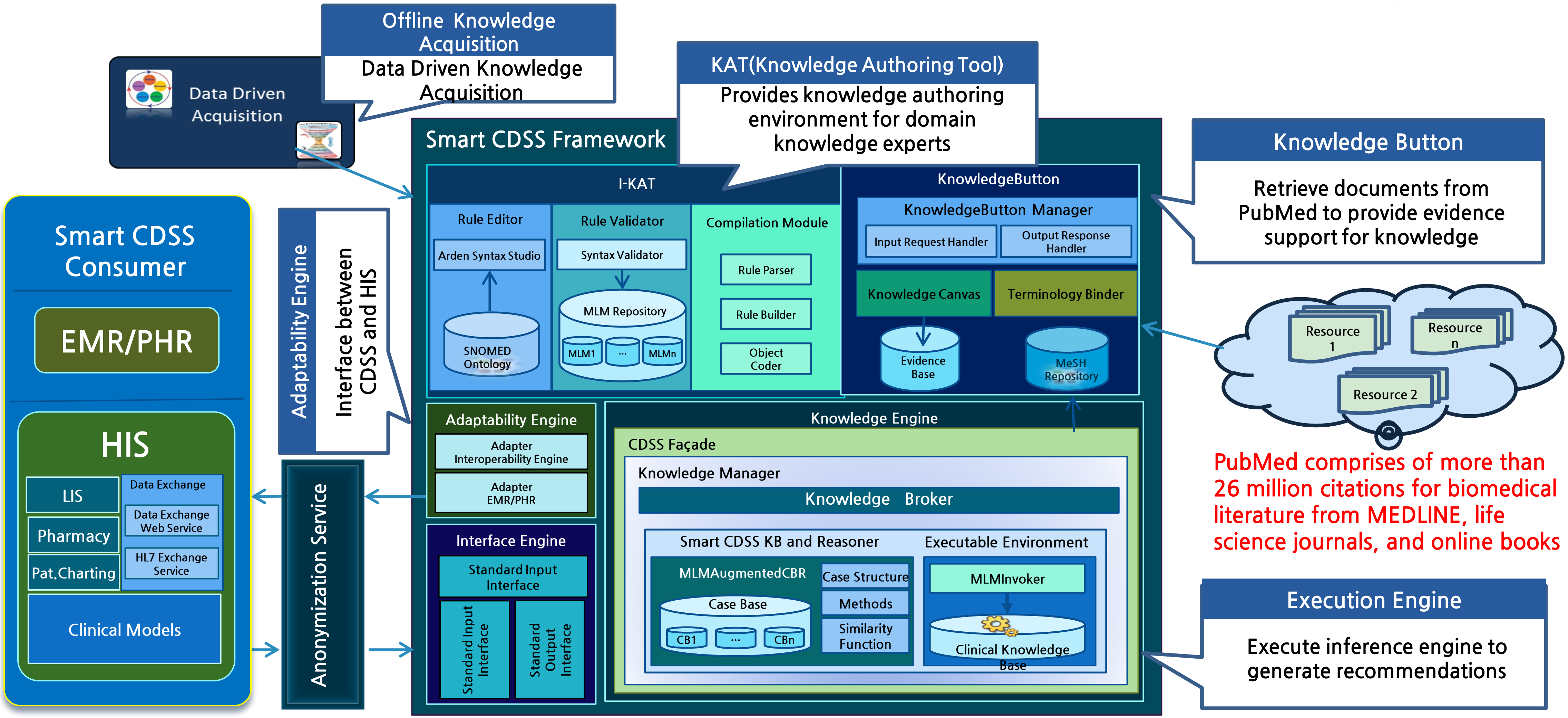
Clinical Decision Support System

Knowledge base requirements	Detail	CASE	Final requirements
Integrity	**Rule (Knowledge creation) should be accurate** — Rule should reflect medical knowledge completely — Rule should be worth enough to be used in the actual medical environment	Rule KB constructed without enough medical knowledge is meaningless	Physicians should generate and maintain the knowledge themselves
Adaptability	**Rule must be customizable based diverse hospital environment** - It should be customizable based on available resources (medical device, inspection device, etc.)	Method of examination, treatment and operation differs based on the devices the hospital owns	
Freshness	**Easy to update new knowledge** - Each time a new treatment, prescription, or surgical procedure is derived, the Rule should be updated on these matters.	Update of new rule should be easy	
Reliability	**Must have sufficient credibility** - Utilized knowledge should have sufficient reliability based on certified thesis, clinical trial data, EMR inference data, etc.	It should be based on thesis, pharmaceutical company clinical trial data, EMR inference data, etc.	Evidence Based

Idea of Smart CDSS

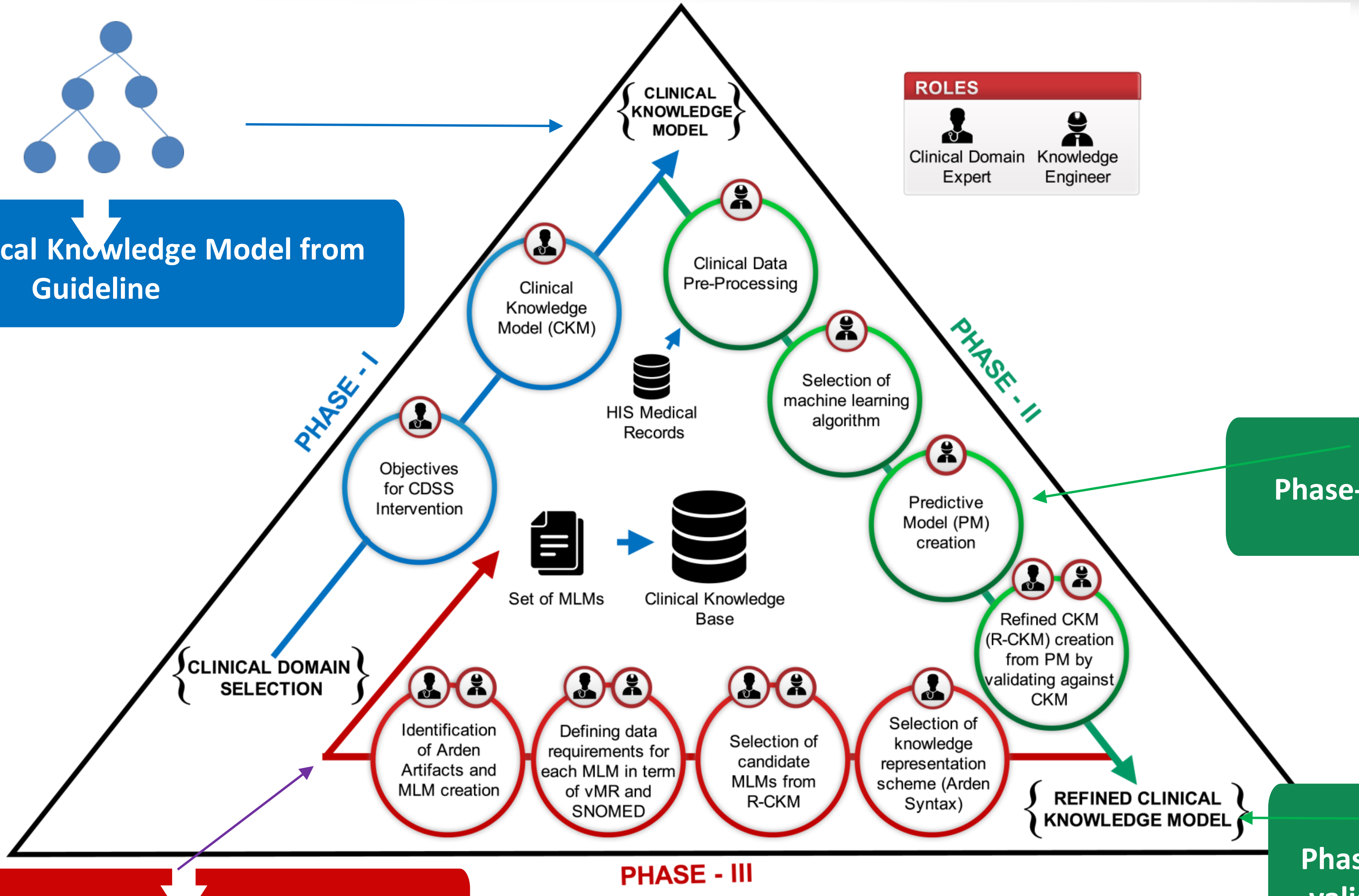


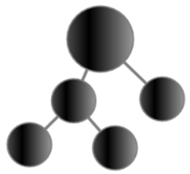
Smart CDSS Architecture



Case Study: Knowledge Acquisition-3 Phase Model

Phase-I: Clinical Knowledge Model from Guideline





Phase-II: Prediction Model from patient medical record (Data Driven)

Phase-II: Refined Clinical Knowledge Model after validation of PM from CKM (Guideline Enabled)

Phase-III: R-CKM Conversion into MLM (Expert Driven)

Case Study: Knowledge Acquisition Pathway

Mind Maps

(Domain Experts Tree Model)

- Consulting guidelines, Clinical Trails, and others
- Incorporating local practices and context

Advantages

- Easy representation (Most domain expert adopt)
- Provide detailed narratives

Limitations

- High abstraction (not explicit knowledge)
- Chance of redundancy & ambiguity

Clinical Knowledge Model

(Decision Tree)

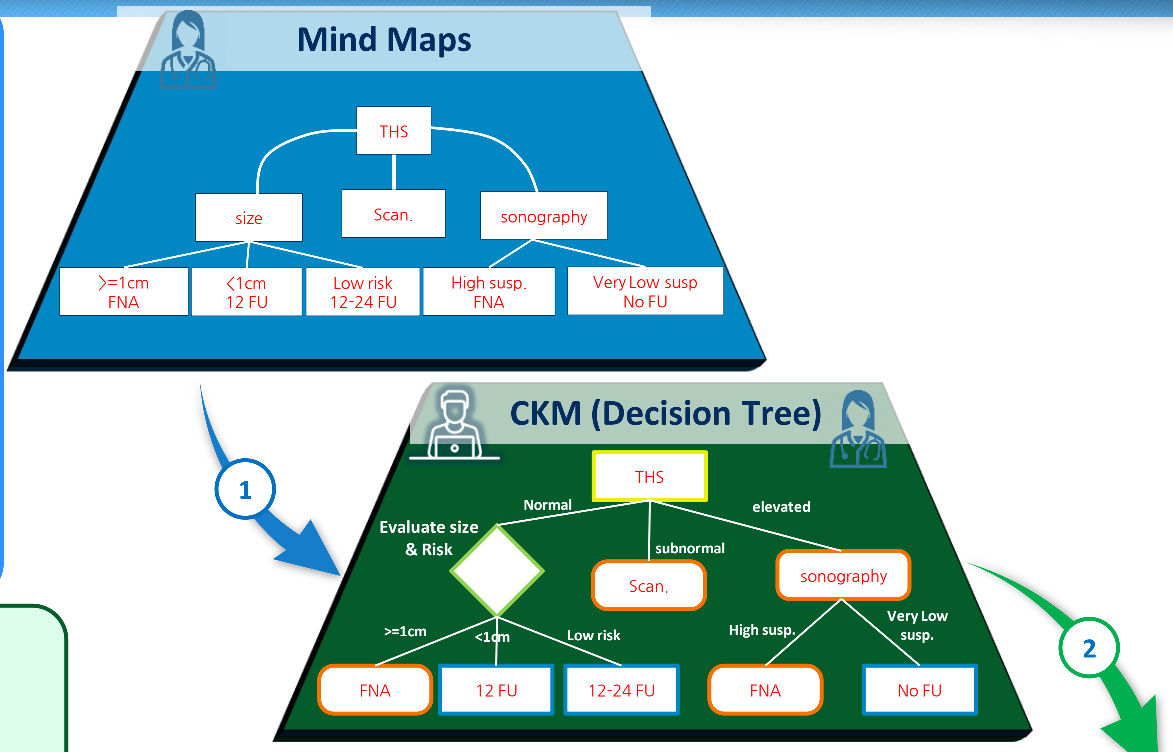
- Separating actions, conditions, and recommendations
- Representation in formal decision tree

Advantages

- Concrete representation (explicit knowledge)
- Remove redundancy & ambiguity (reduce error chance)
- Provide detailed narratives

Limitations

- Adoption needs to follow formalism
- Non-executable by computer



Knowledge-base

(Production Rules: PR)

- CKM -> rules using top-down: left-right traversing
- Conversion of OR into ANDs in PR

Advantages

- Concrete representation (explicit knowledge)
- Computer executable representation

Limitations

- Non-sharable

Knowledge-base

(Medical Logic Module: MLM)

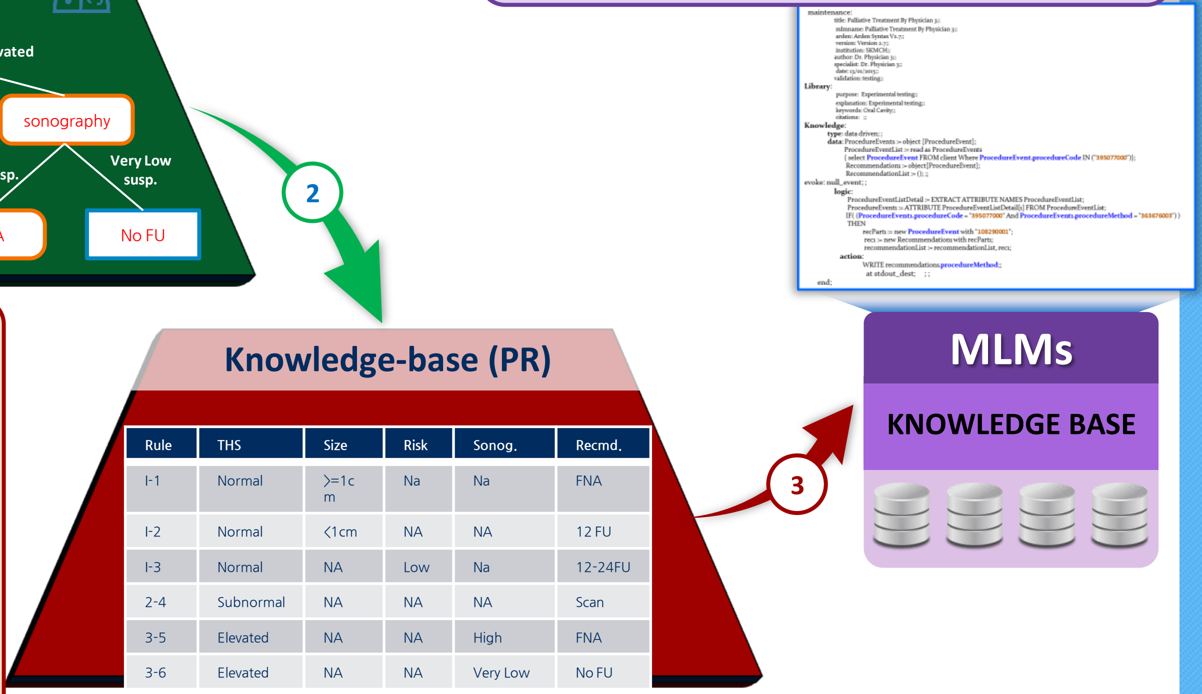
- Combining PRs into coherent logics
- Represent concepts in standard format

Advantages

- Sharable and executable representation
- Concrete representation (explicit knowledge with detailed meta-data support)

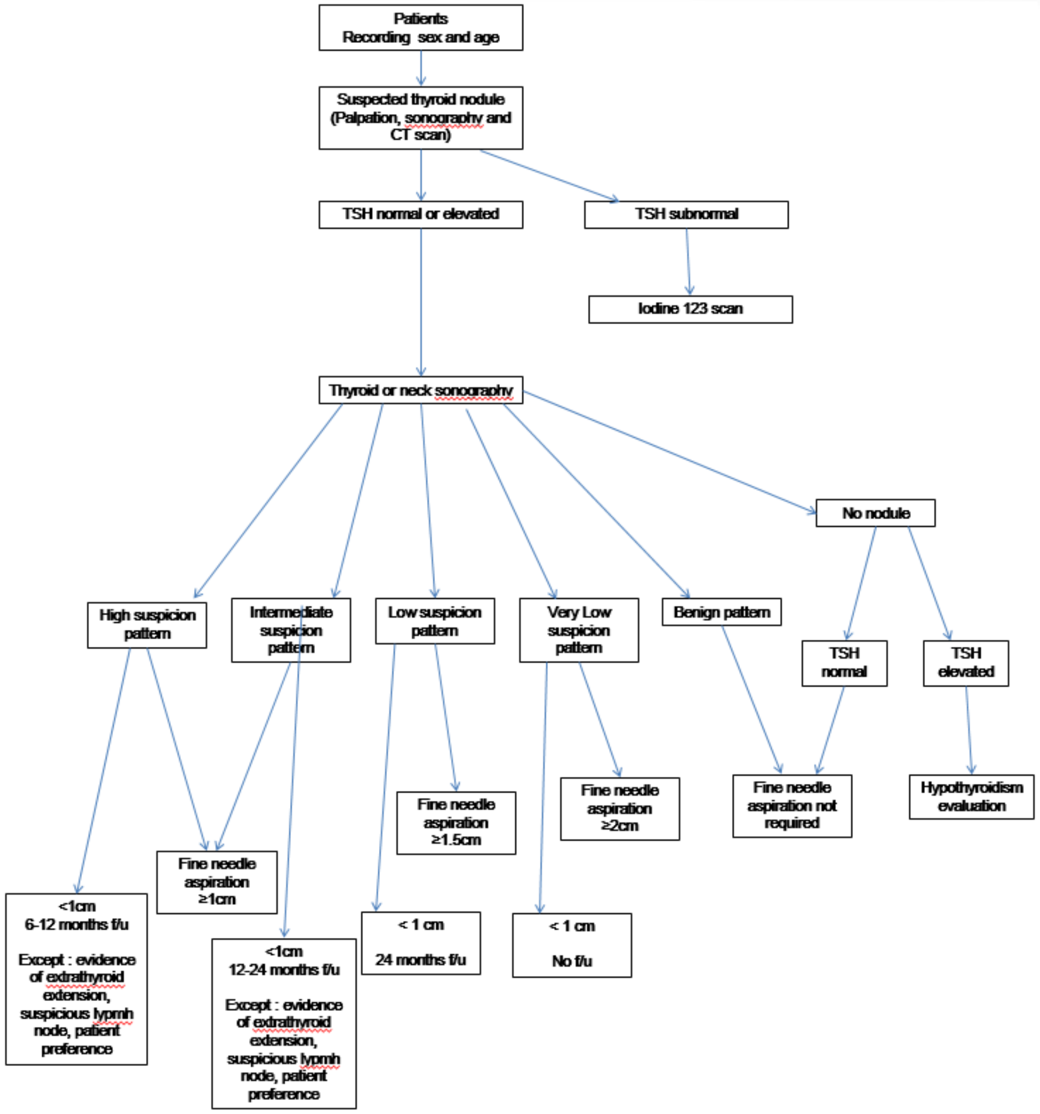
Limitations

- Complex compared to PR



Case Study: Knowledge Modeling for Thyroid Cancer

Mind Maps Development Process – Example SNU Hospital

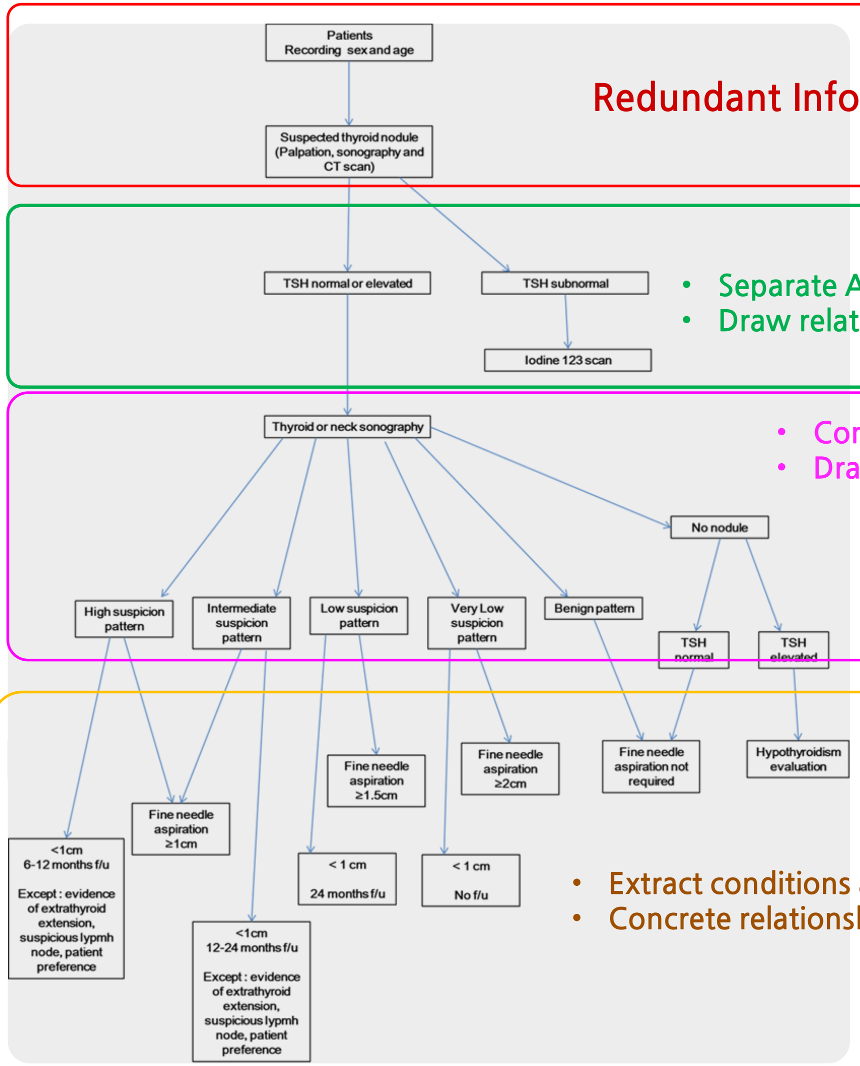


Guideline based strategy

1. *Patient initial observation for tumor presence*
2. *Ordering sonography*
3. *Evaluate sonography results and evaluate patients*
4. *Based on severity and size of the tumor, decision is made for further Surgery evaluation using FNA*

Case Study: Thyroid Cancer Follow Up Recommendation

Expert Tree (Mind Maps) -> Formal Decision Tree (CKM-Clinical Knowledge Model)

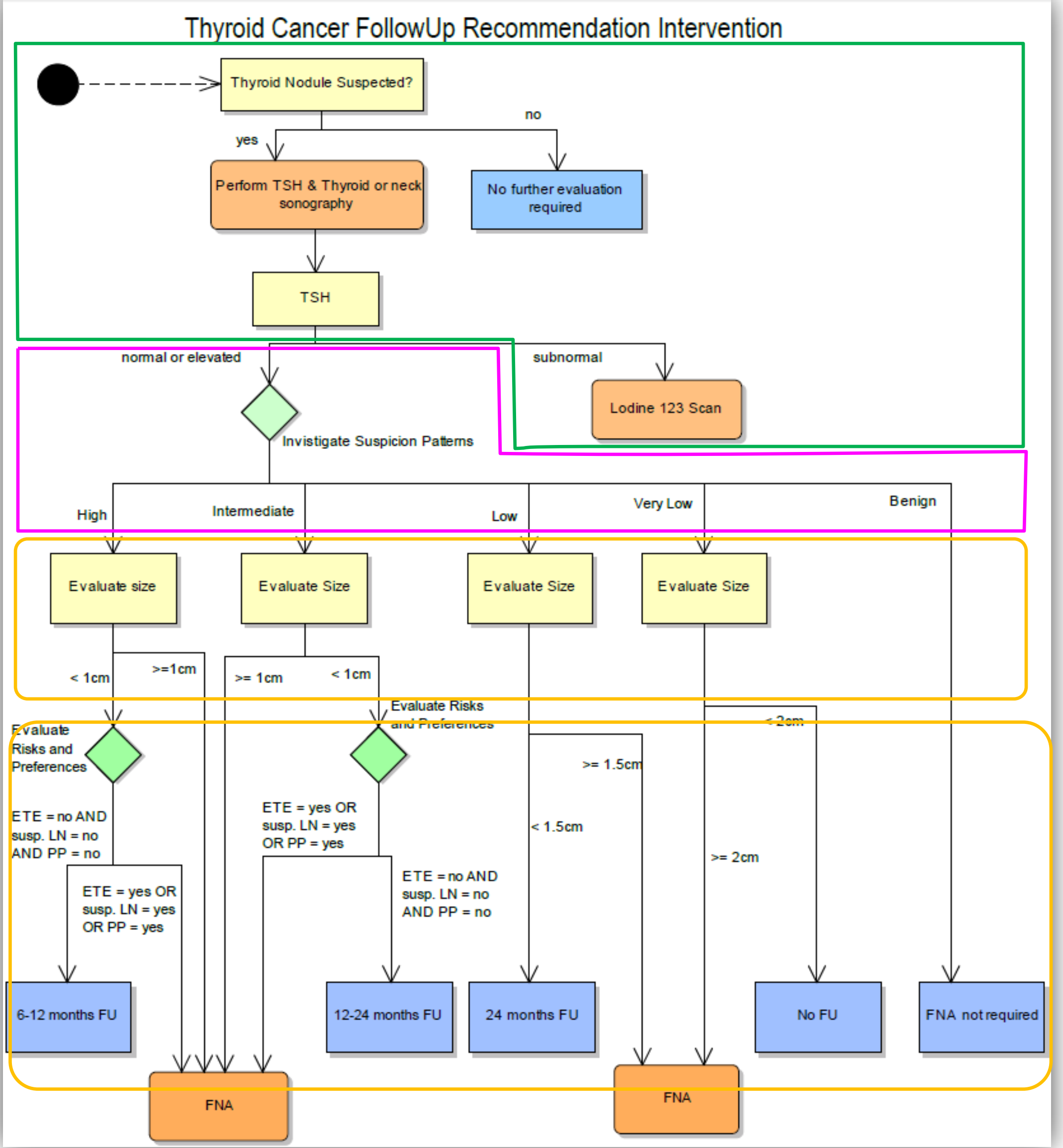


Redundant Information X

- Separate Actions & Conditions
- Draw relationships

- Composite condition
- Draw relationships

- Extract conditions and recommendation
- Concrete relationships



Case Study: Thyroid Cancer Follow Up Recommendation

Formal Decision Tree (CKM-Clinical Knowledge Model) -> Rules (Production Rules)

1

Rule#	Thyroid Nodule Expected	TSH	Suspicion Patterns	Size	ETE	susp. LN	PP	Treatment-Decision
1	yes	normal	High	<1cm	no	no	no	6-12 months follow up
2	yes	normal	High	<1cm	yes	no	no	FNA
3	yes	normal	High	<1cm	no	yes	no	FNA
4	yes	normal	High	<1cm	no	no	yes	FNA
5	yes	normal	High	<1cm	yes	yes	no	FNA
6	yes	normal	High	<1cm	yes	no	yes	FNA
7	yes	normal	High	<1cm	no	yes	yes	FNA
8	yes	normal	High	<1cm	yes	yes	yes	FNA
9	yes	normal	High	>=1cm	-	-	-	FNA
10	yes	elevated	High	<1cm	no	no	no	6-12 months follow up
11	yes	elevated	High	<1cm	yes	no	no	FNA
12	yes	elevated	High	<1cm	no	yes	no	FNA
13	yes	elevated	High	<1cm	no	no	yes	FNA
14	yes	elevated	High	<1cm	yes	yes	no	FNA
15	yes	elevated	High	<1cm	yes	no	yes	FNA

Traversing:

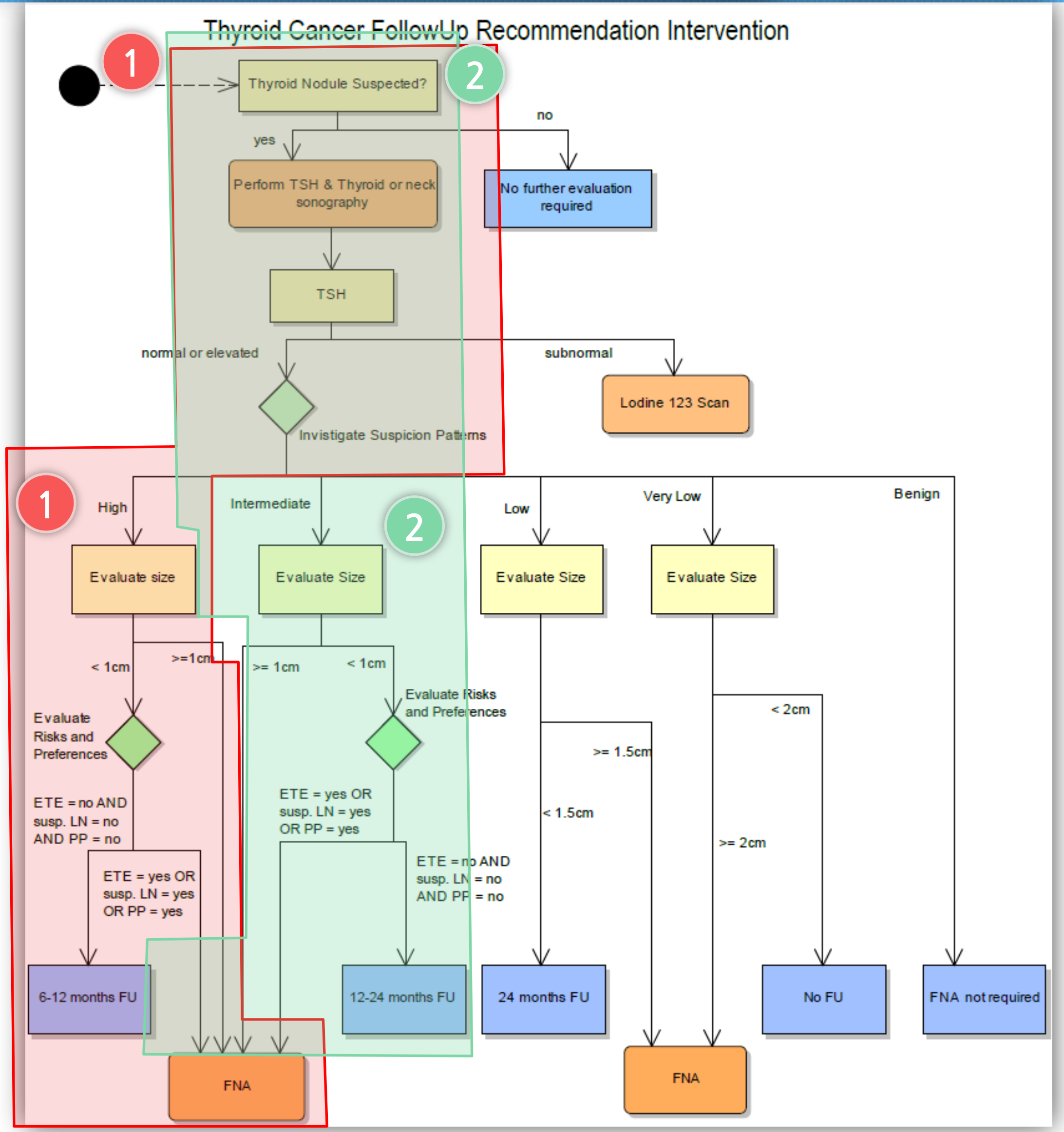
- **Top-Down**

2

35	yes	elevated	Intermediate	<1cm	yes	yes	yes	FNA
36	yes	elevated	Intermediate	<1cm	no	no	no	12-24 months follow up
37	yes	normal	Low	<1.5cm	-	-	-	24 months follow up
38	yes	normal	Low	>=1.5cm	-	-	-	FNA
39	yes	elevated	Low	<1.5cm	-	-	-	24 months follow up
40	yes	elevated	Low	>=1.5cm	-	-	-	FNA
41	yes	normal	Very Low	>=2cm	-	-	-	FNA
42	yes	normal	Very Low	<2cm	-	-	-	No follow up
43	yes	elevated	Very Low	>=2cm	-	-	-	FNA
44	yes	elevated	Very Low	<2cm	-	-	-	No follow up
45	yes	normal	Benign	-	-	-	-	FNA not required

Traversing:

- **Left-Right**

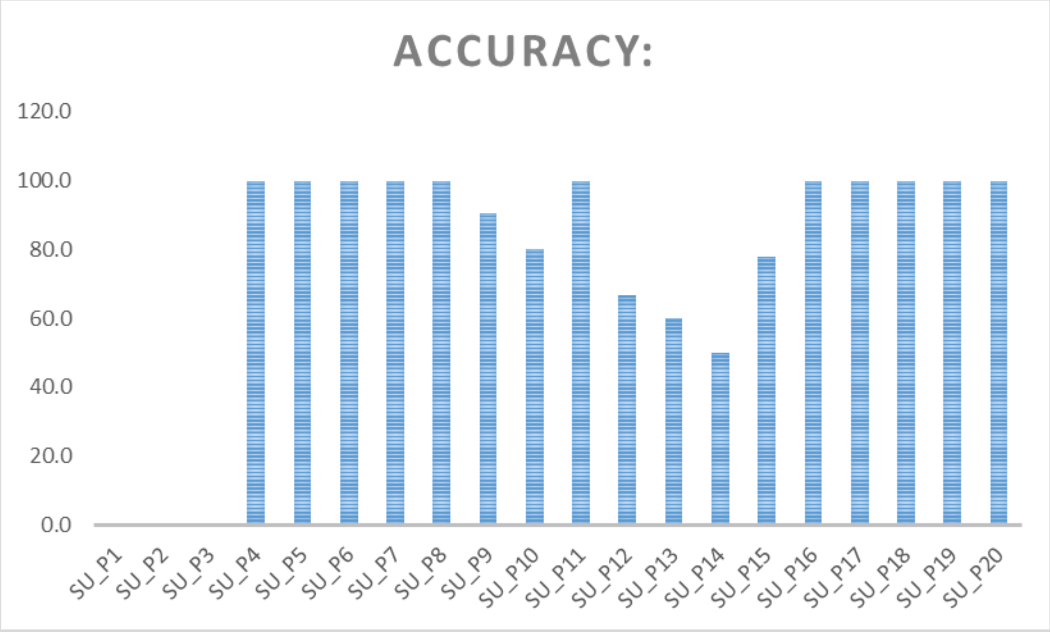


Case Study: Results

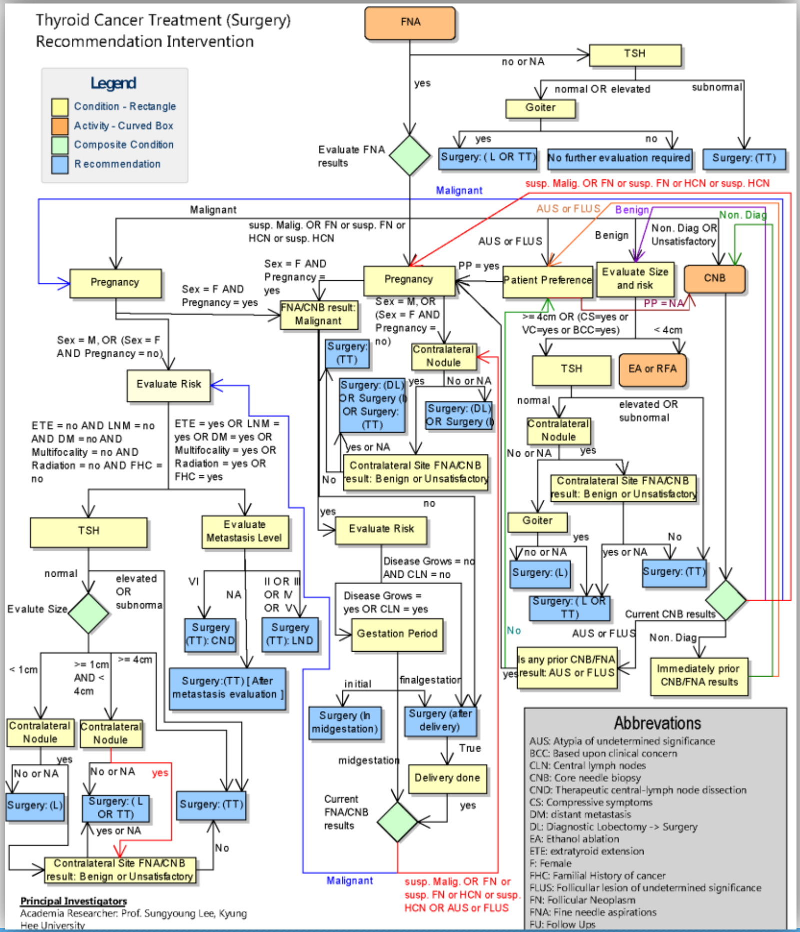
Surgery Paths	SU_P1	SU_P2	SU_P3	SU_P4	SU_P5	SU_P6	SU_P7	SU_P8	SU_P9	SU_P10	SU_P11	SU_P12	SU_P13	SU_P14	SU_P15	SU_P16	SU_P17	SU_P18	SU_P19	SU_P20	Total Patients
Patients:	2	3	1	15	4	8	3	1	43	55	1	3	10	2	123	1	1	9	2	5	292
Pat: S:	0	0	0	15	4	8	3	1	39	44	1	2	6	1	96	1	1	9	2	5	238
Pat: F:	2	3	1	0	0	0	0	0	4	11	0	1	4	1	27	0	0	0	0	0	54
Accuracy:	0.0	0.0	0.0	100.0	100.0	100.0	100.0	100.0	90.7	80.0	100.0	66.7	60.0	50.0	78.0	100.0	100.0	100.0	100.0	100.0	81.5

Interpretation:

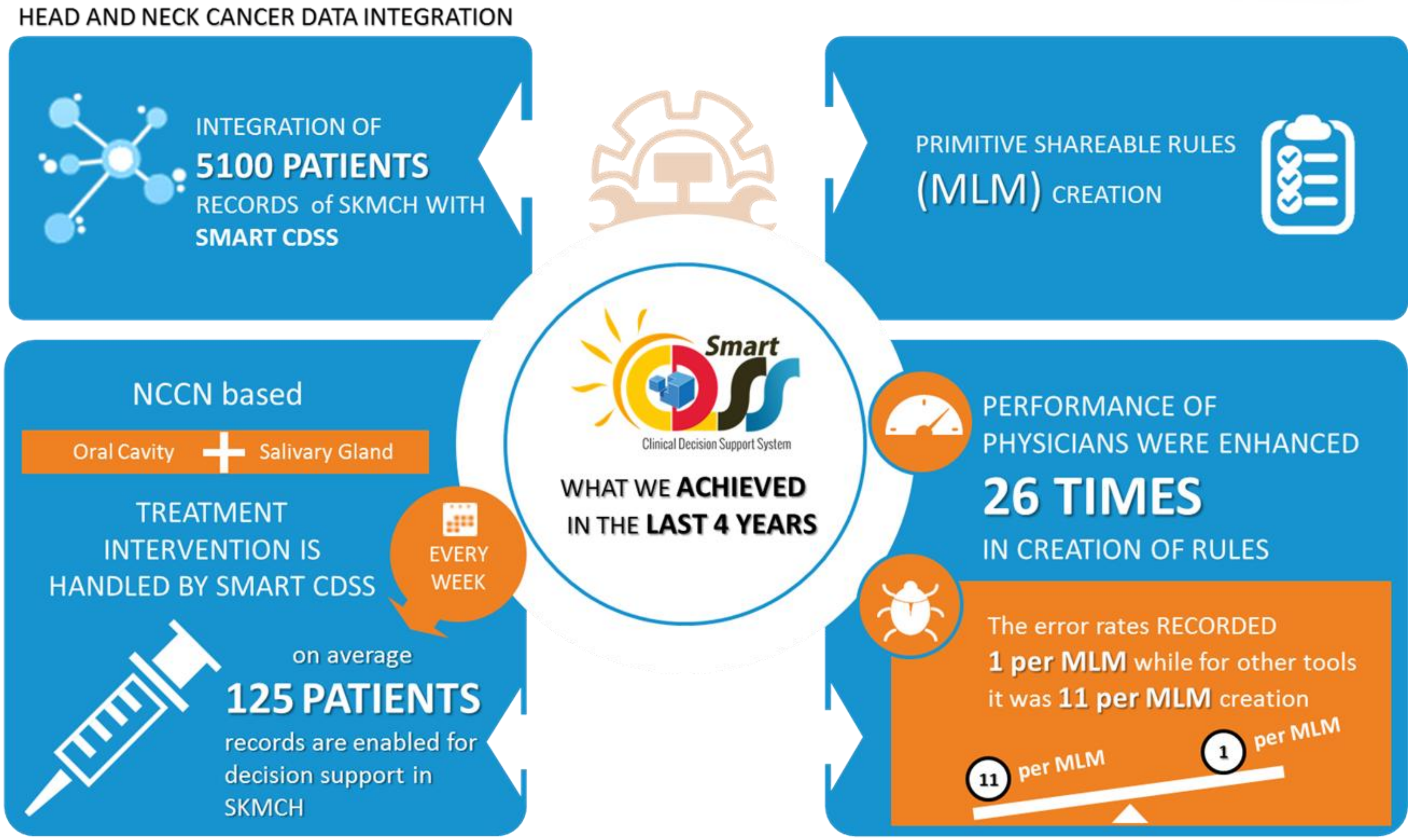
- ***Total Patients : 292***
- ***Patient Distribution: 20 paths***



System Accuracy: 81.5%
Overall KB rules: 3034



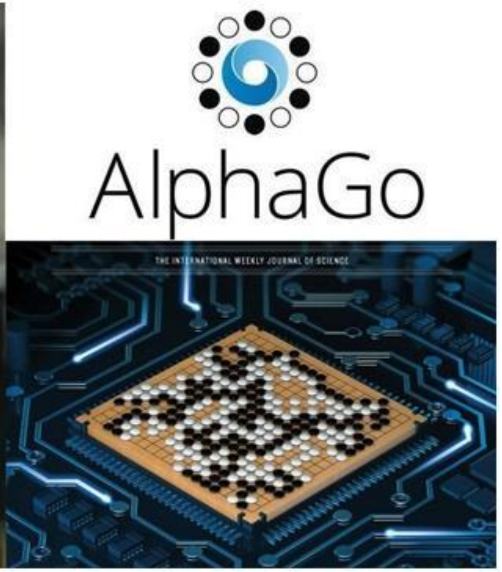
Achievements of Smart CDSS

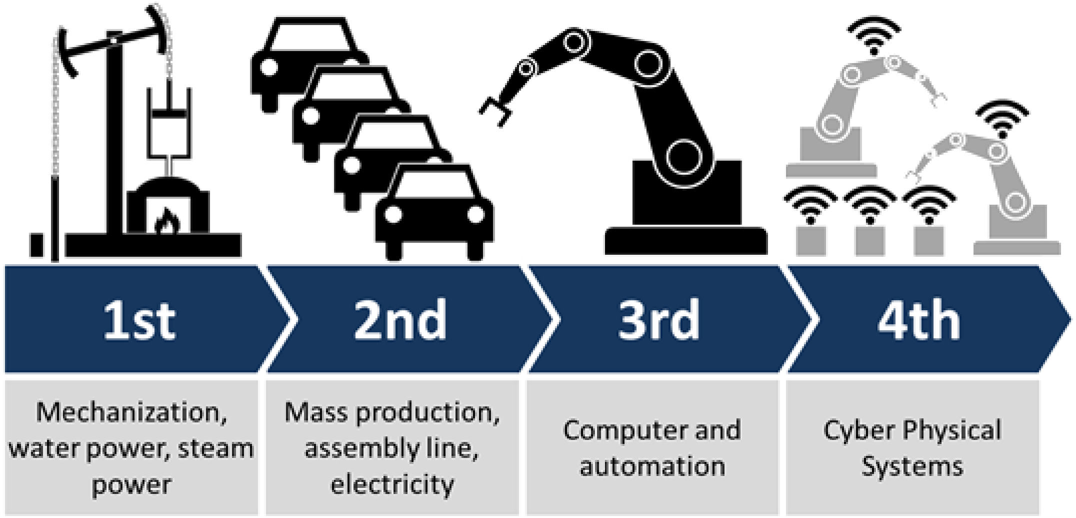


Intelligent Medical Platform

New Waves

- ✓ Artificial Intelligence Society
- ✓ 4th Industrial Revolution
  -> Increased Productivity by Super Connectivity and Super Intelligence





Background

AI in Medical Service Systems – AI Doctor

Korea	International
SK telecom, KOREA UNIVERSITY MEDICAL CENTER: Physician's prescription and diagnosis support system using voice recognition so called AI 'NUGU'	Google DeepMind, NHS England: Intelligent diagnosis system using 1.6 million patient's medical data in NHS, UK
kt, NATIONAL CANCER CENTER: Medical big data cloud infrastructure with patient's gene and clinical information	IBM: Next generation AI assistance system which has a reasoning ability
Lunit, SNUH SEOUL NATIONAL UNIVERSITY HOSPITAL, 세브란스병원 SEVERANCE HOSPITAL: AI based Diagnosis system for lung disease, pneumonia and breast cancer using chest x-ray image	Microsoft, OREGON HEALTH & SCIENCE UNIVERSITY: Conducting Hanover project where AI can offer the best effective medication by analyzing state of tumor

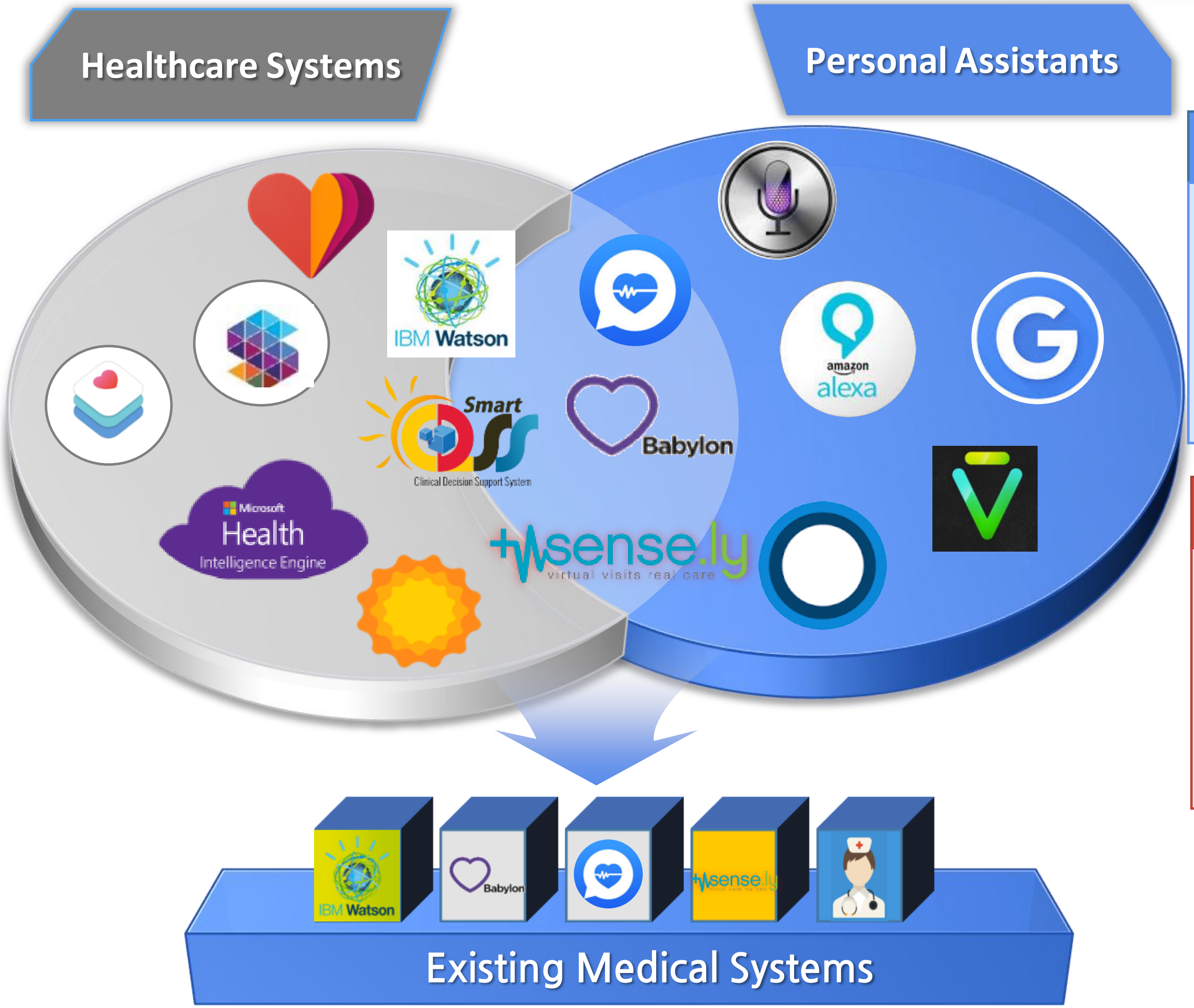
Background: Healthcare Systems vs Personal Assistants

Strength

- ❑ Actionable Knowledge
- ❑ Empowering the expert user
- ❑ Evidence support for domain experts

Weakness

- ❑ **Non-Interactive**
- ❑ **Rigid Knowledge Structures**
- ❑ **Lack Context-awareness**



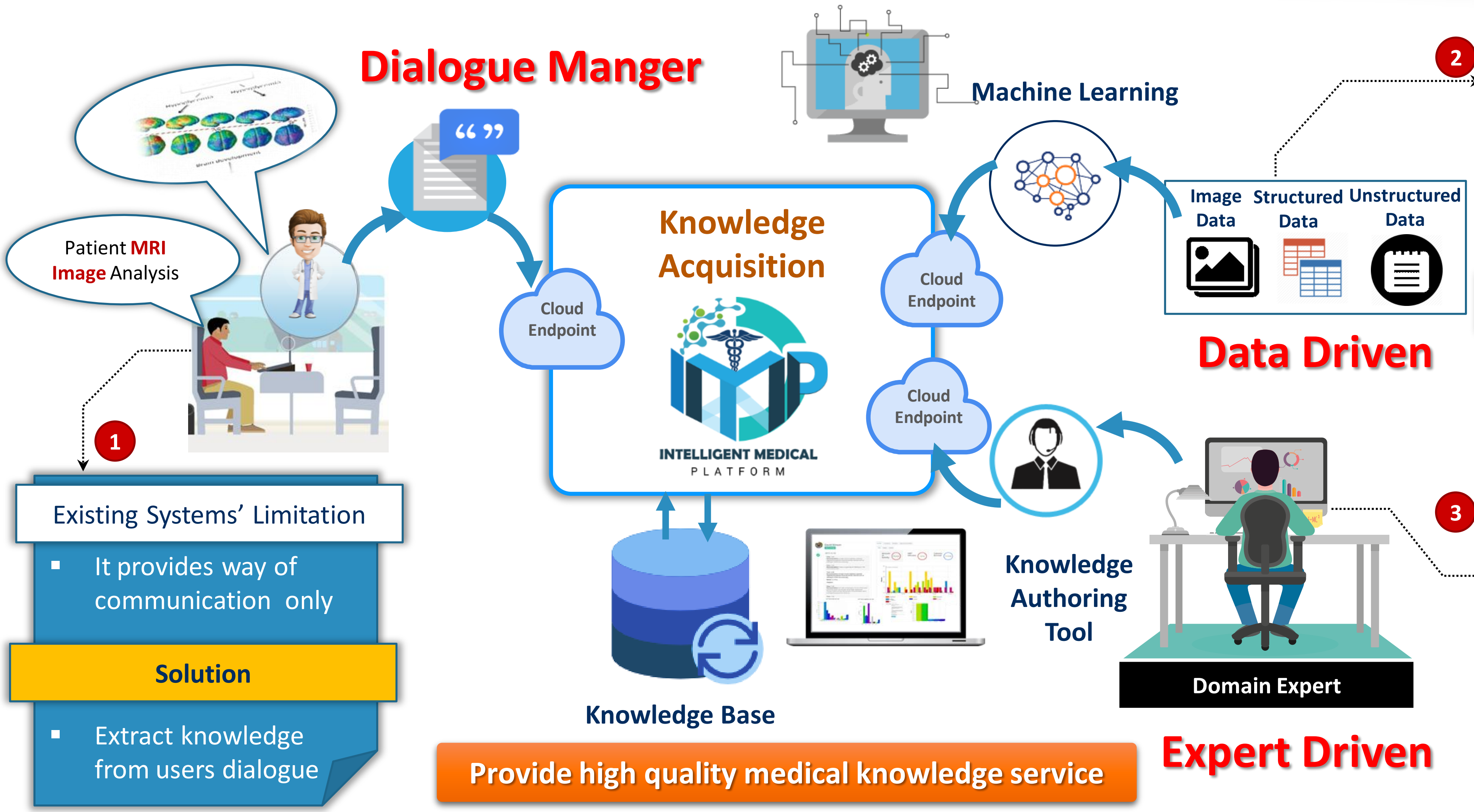
Strength

- ❑ Highly Interactive
- ❑ Natural User Interfaces
- ❑ User Engagement

Weakness

- ❑ **No Actionable Knowledge**
- ❑ **No Concept of appraised evidence support**
- ❑ **Limited Visual Understanding**

New Requirements: Methods for Knowledge Acquisition



1

Existing Systems' Limitation

- It provides way of communication only

Solution

- Extract knowledge from users dialogue

2

Existing Systems' Limitation

- Deep learning algorithm cannot provide reason of decision making (Black box)

Solutions

- Using white box AI techniques to create knowledge base

3

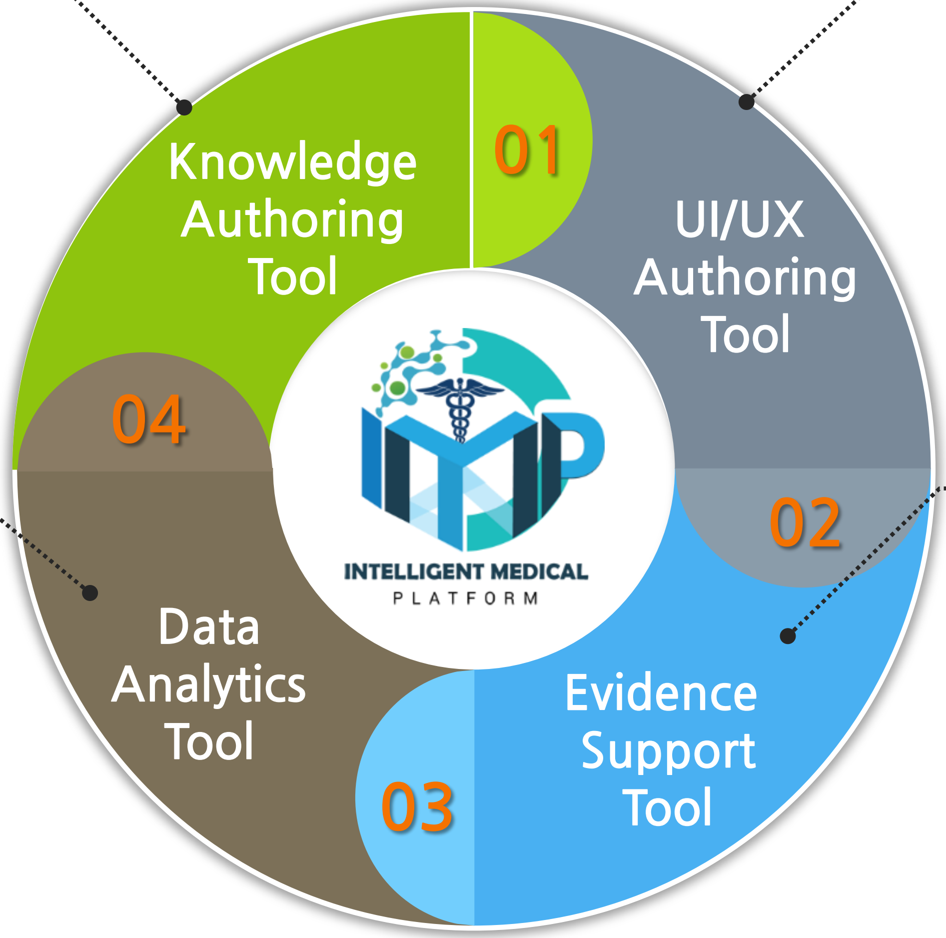
Existing Systems' Limitation

- lack of verification and validation for huge number of rules.

Solutions

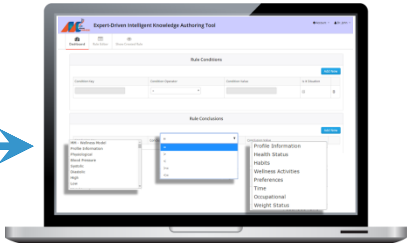
- Incremental Knowledge acquisition

New Requirements: Engineering Tool Support

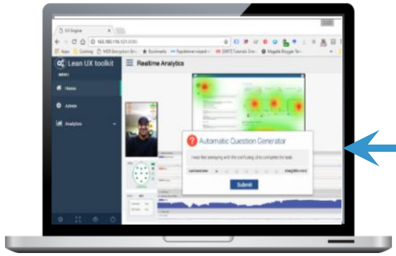


- Incremental Learning-based validation and verification
- Intelli-sense support

Physician



- Overall UX quantification over time
- Adaptive UI based on UX



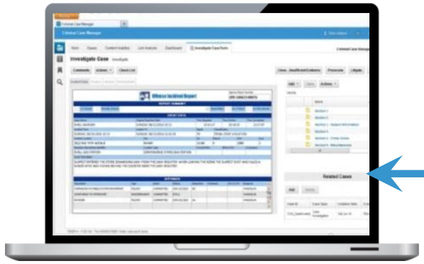
UX Expert

- Real time monitoring
- Health-log visualization

Patient

Physician

- Evidence support form PubMed
- Quality assessment retrieved documents



Physician

Easy to commercialize by providing development environment

Genetic Requirements: Considering Factors in Medical Systems

Credible

Secure

Personalized

Reliable

Accurate

Transparent

Context Aware

Easy to use

Source: Little, L. and Briggs, P., "Ubiquitous Healthcare: Do we want it?" Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction-Volume 2, 2008

Motivations: Limitations and Solutions

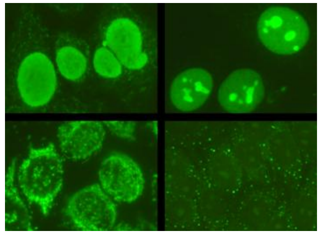
Existing Medical Systems

INTELLIGENT MEDICAL PLATFORM

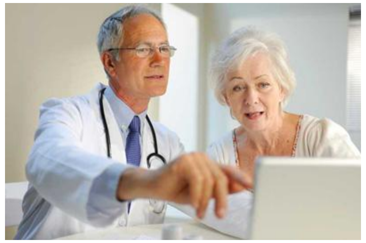
Limitations	Solutions
Restricted Method of Knowledge Acquisition	Data Driven and Human Driven Knowledge Acquisition with Dialogue
Difficult to Knowledge Construction & Maintenance	Knowledge Authoring Tools
Minimum level of Evidence Support	Evidence Supporting Tools (for PubMed)
Poor User's Interaction	Dialogue & UI/UX Tools
Lack of Interoperability in Heterogeneous EMR/HIS	Standard based Mapping and Interoperability Methods

Intelligent Medical Platform

Clinical Decision Support Systems



Clinical diagnosis

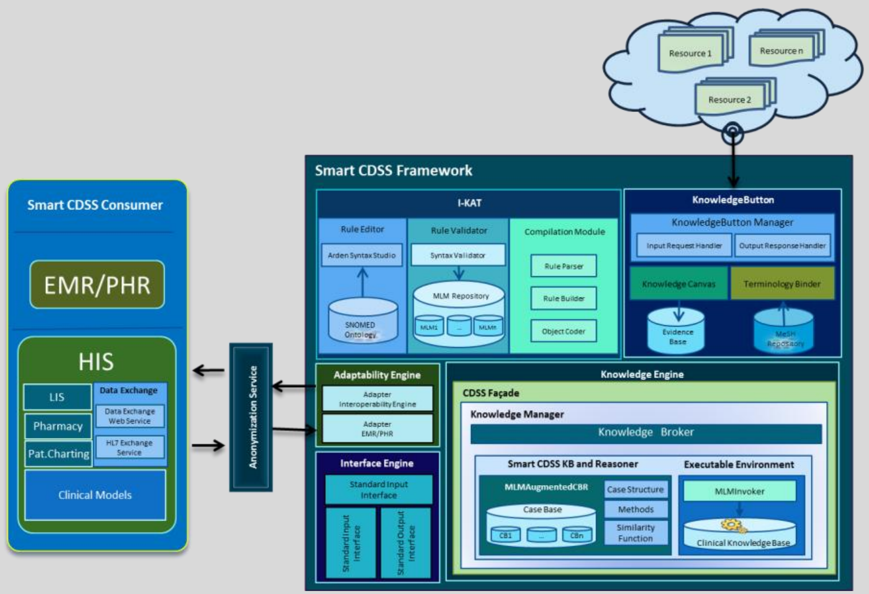


Patient education

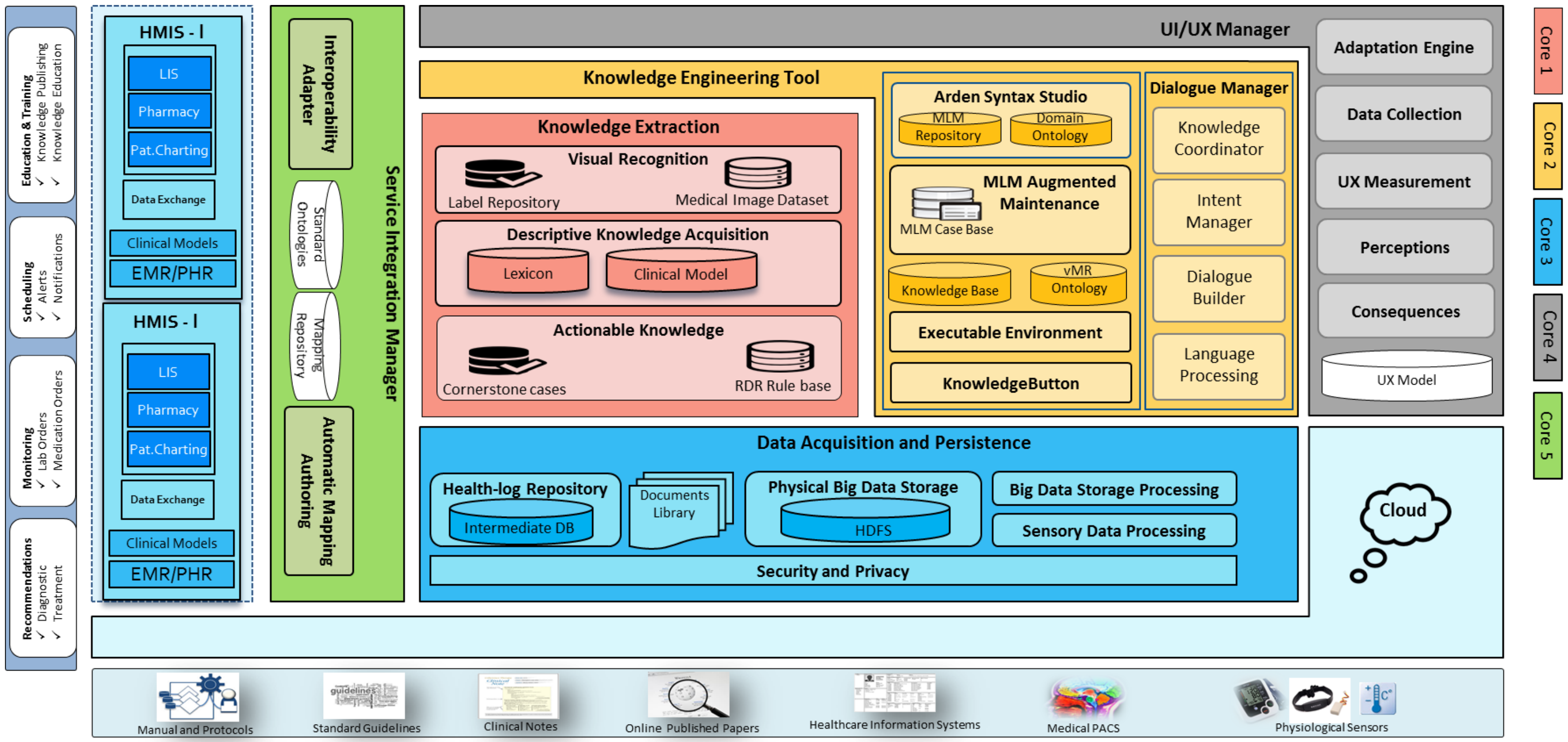
Intelligent communications

Proposed IMP: AS-IS vs TO-BE

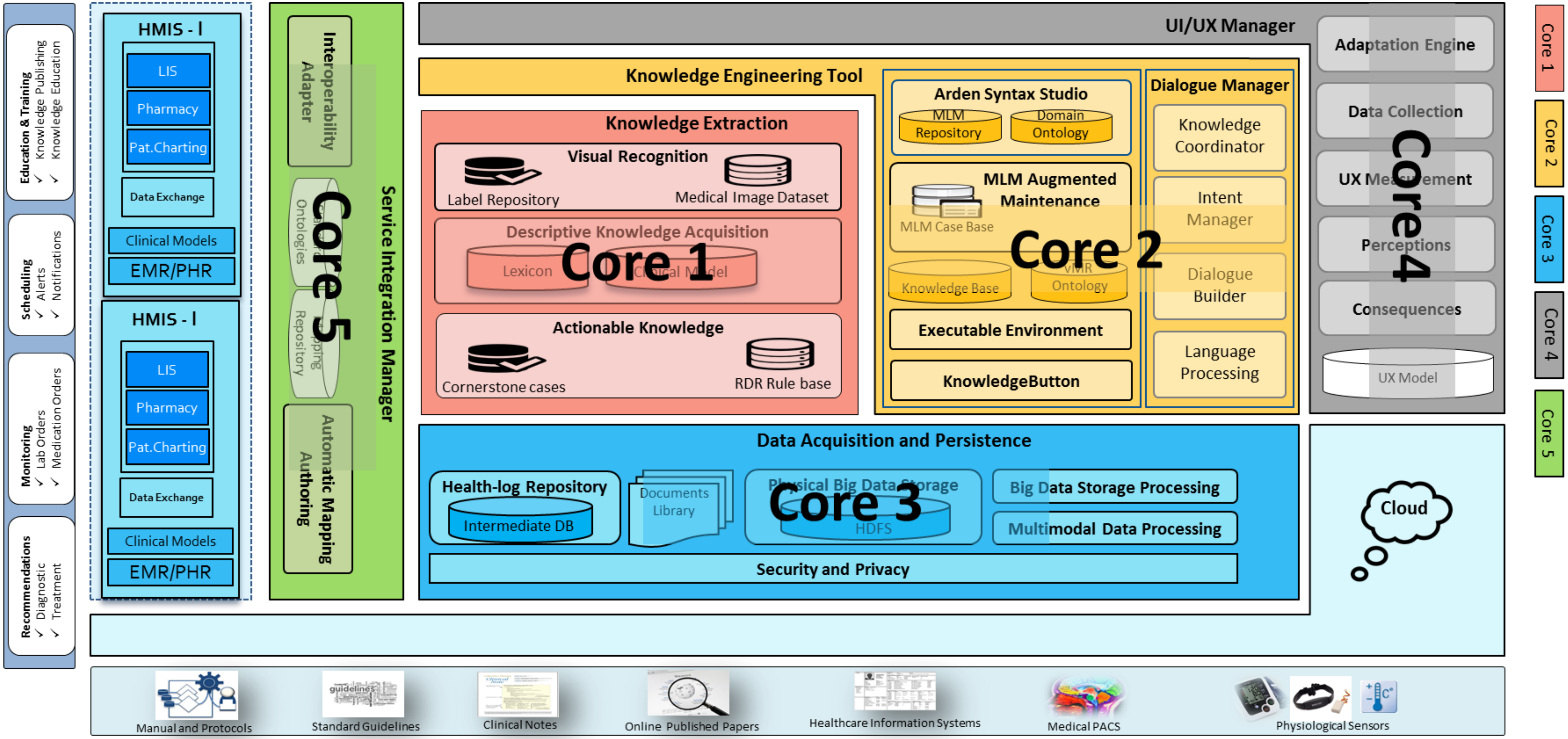
AS IS: Smart CDSS



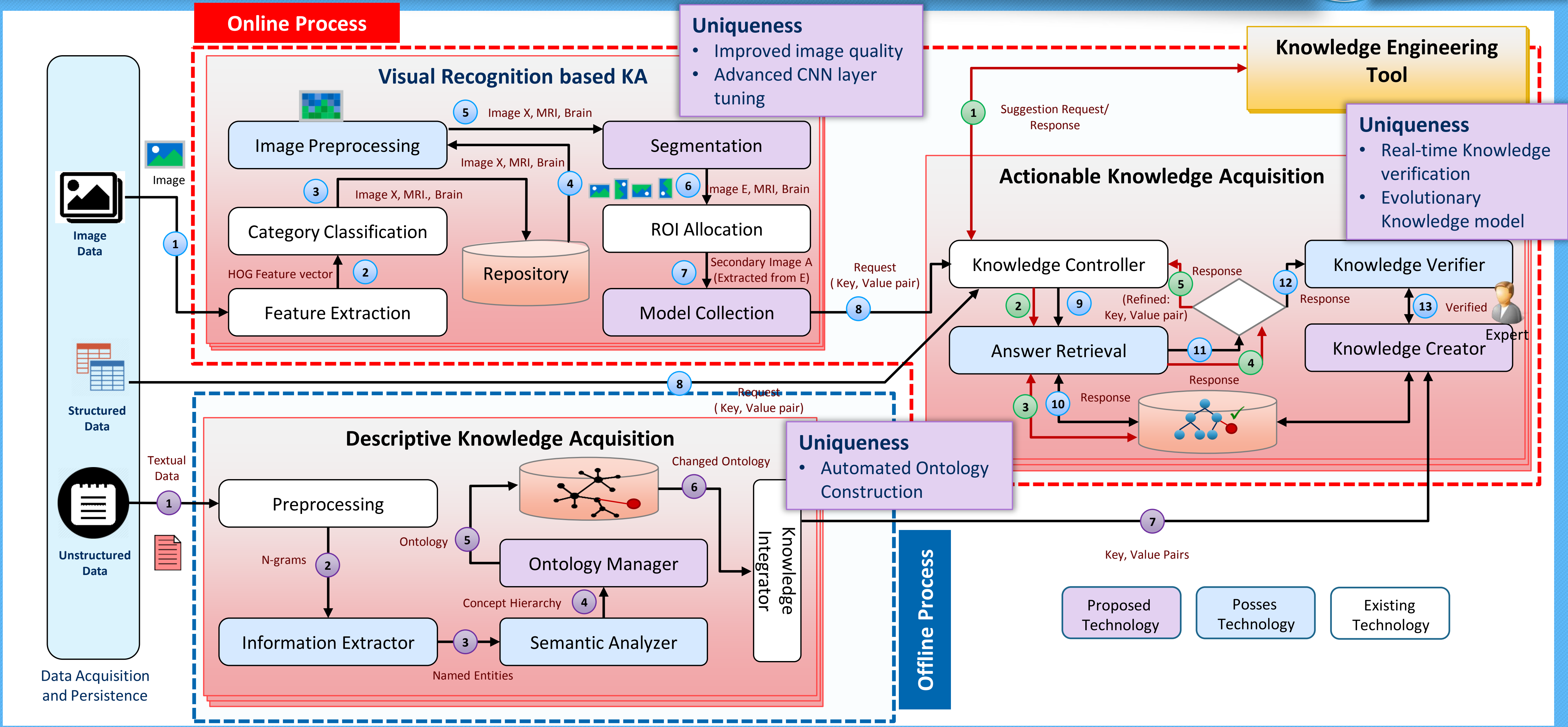
TO BE: Intelligent Medical Platform (IMP)



Proposed IMP (Intelligent Medical Platform) Architecture

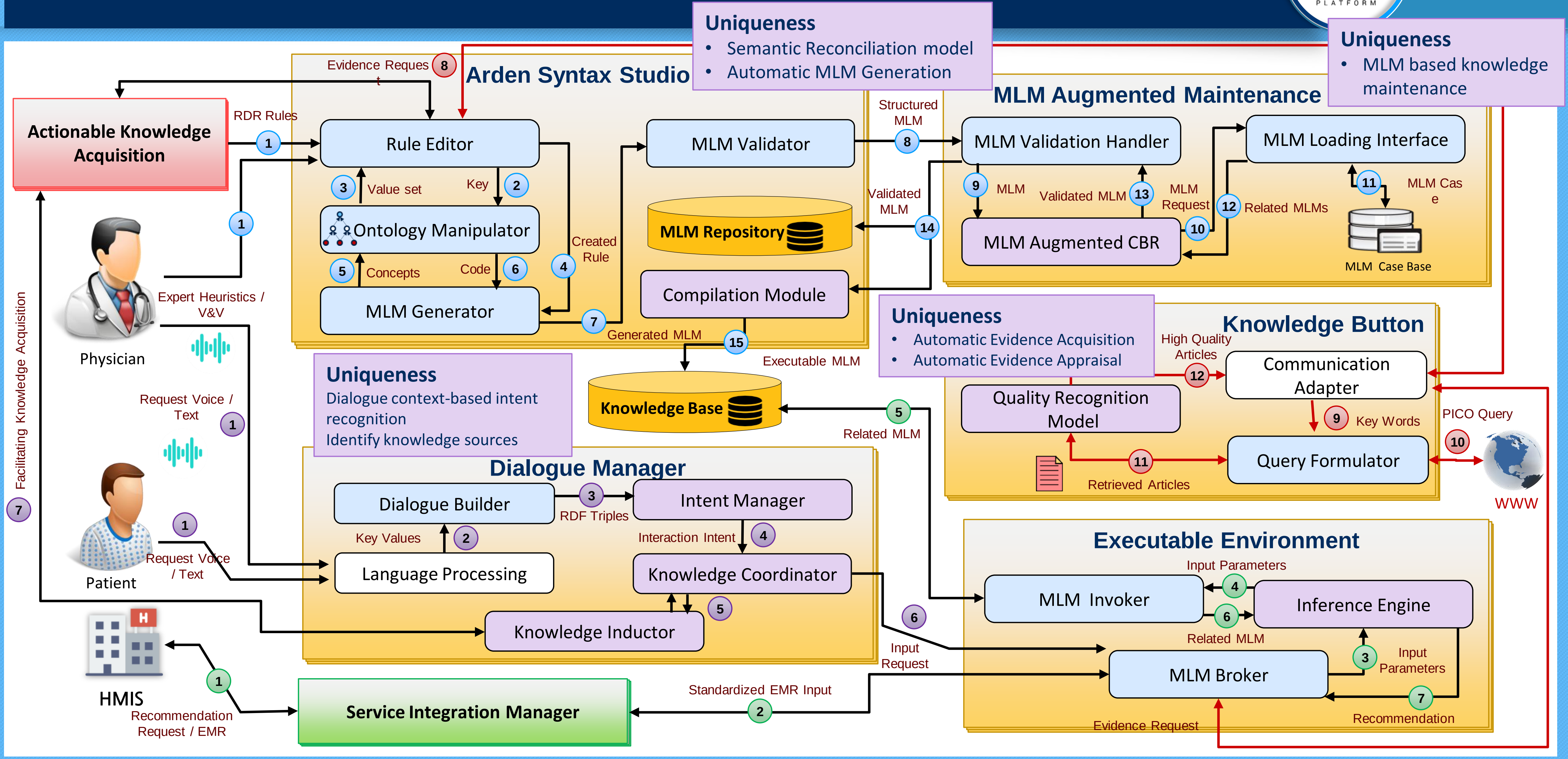


Core 1: Knowledge Acquisition and Inference



Core 2: Knowledge Engineering Tool

Proposed Technology
Posses Technology
Existing Technology

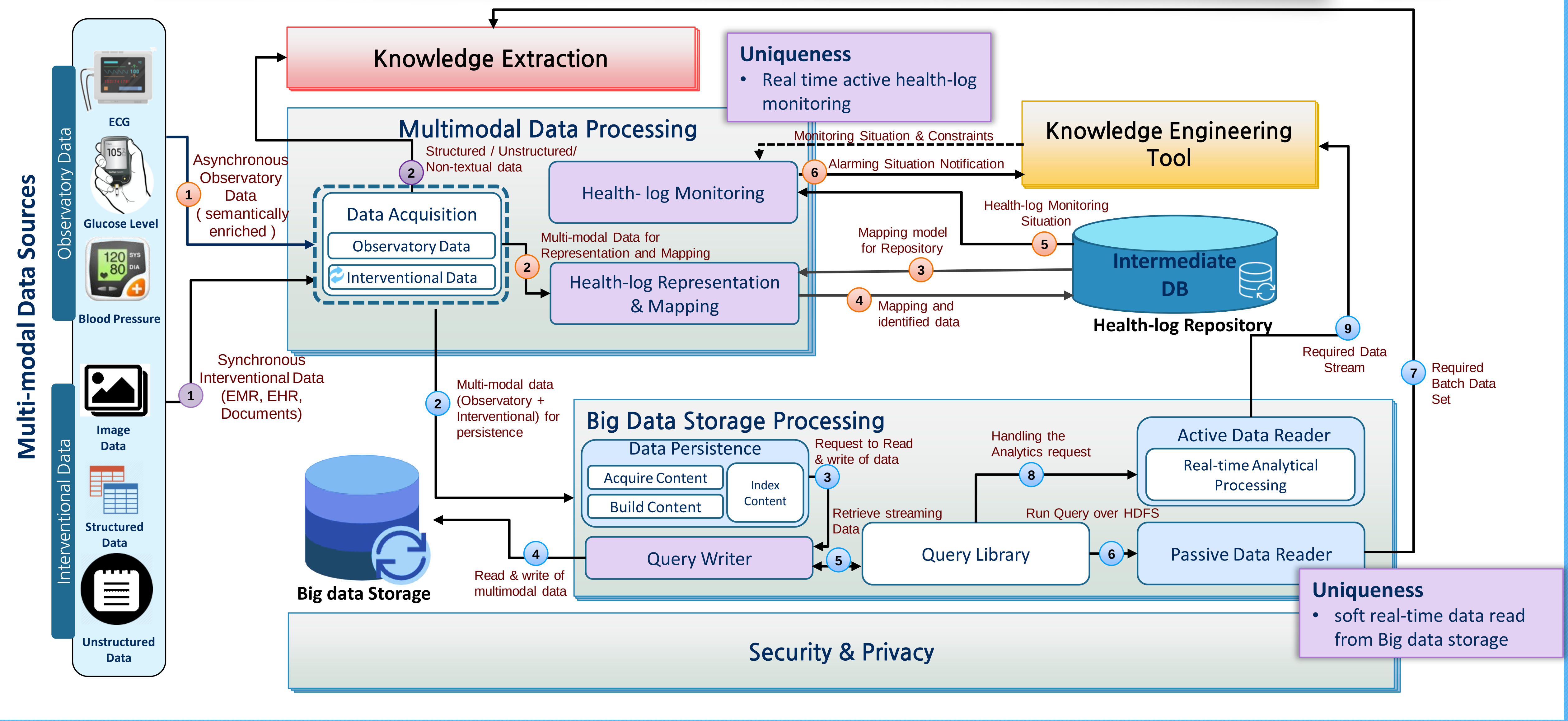


Core 3: Big Data Processing and Storage

Proposed Technology

Posses Technology

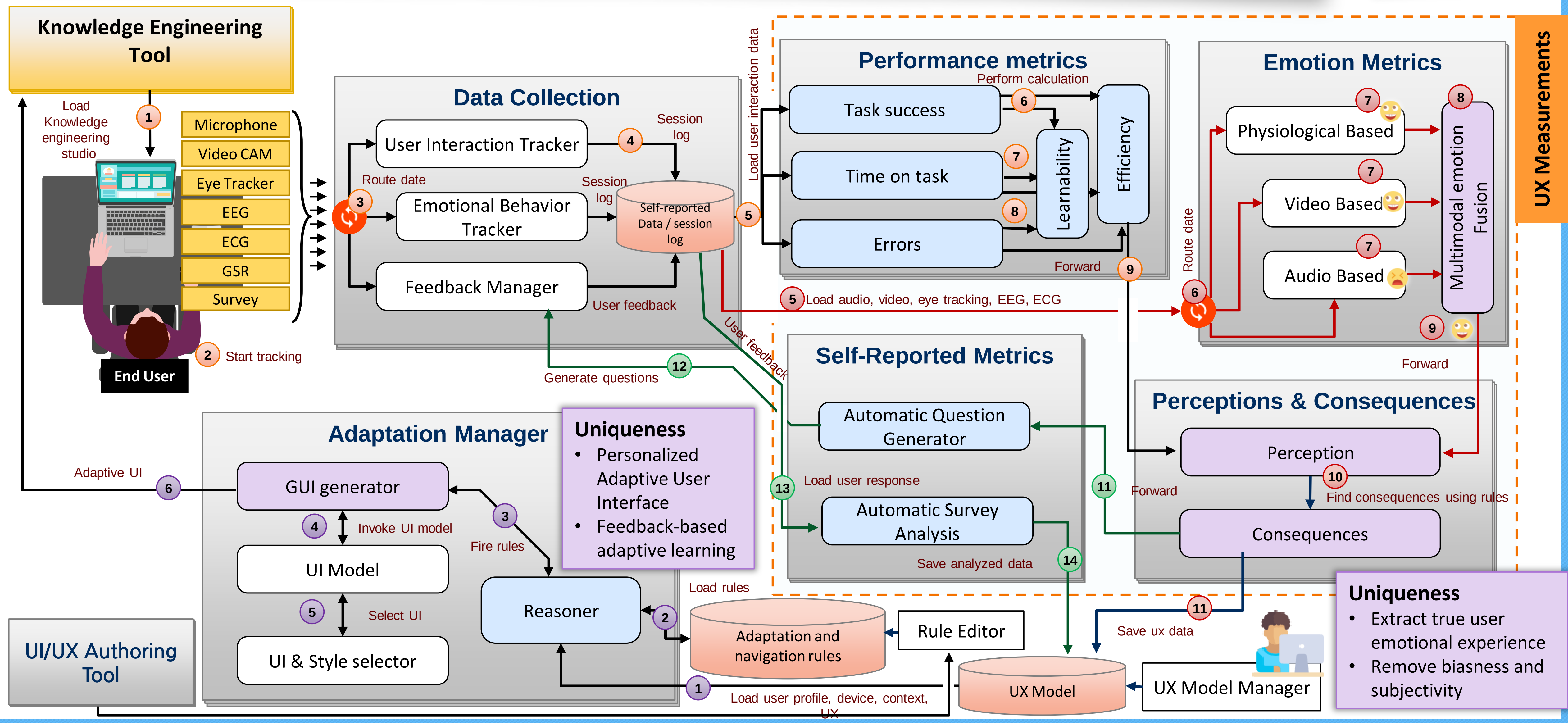
Existing Technology



Core 4: UI/UX Evaluation and Management

Proposed Technology | Posses Technology | Existing Technology

INTELLIGENT MEDICAL PLATFORM



Uniqueness

- Personalized Adaptive User Interface
- Feedback-based adaptive learning

Uniqueness

- Extract true user emotional experience
- Remove biasness and subjectivity

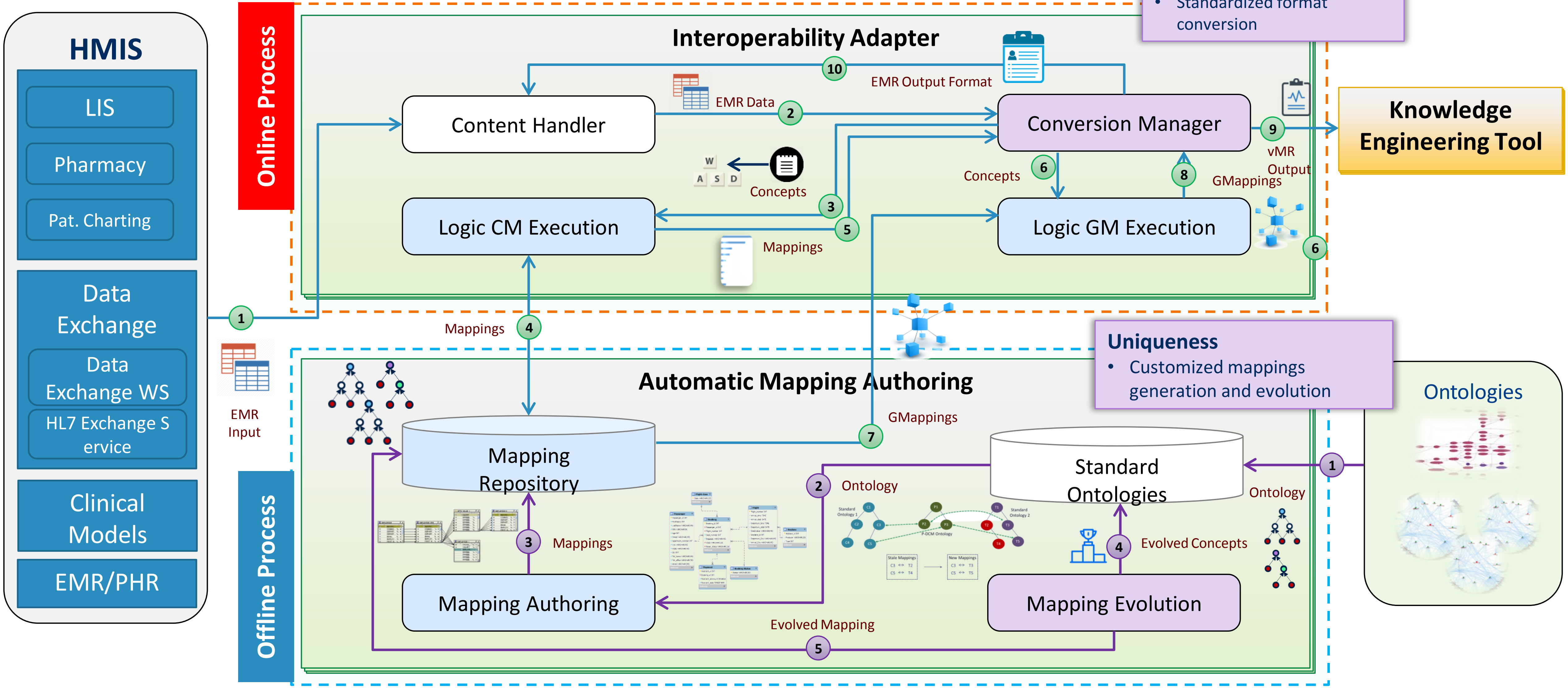
Core 5: Medical Service Integration

Proposed Technology

Posses Technology

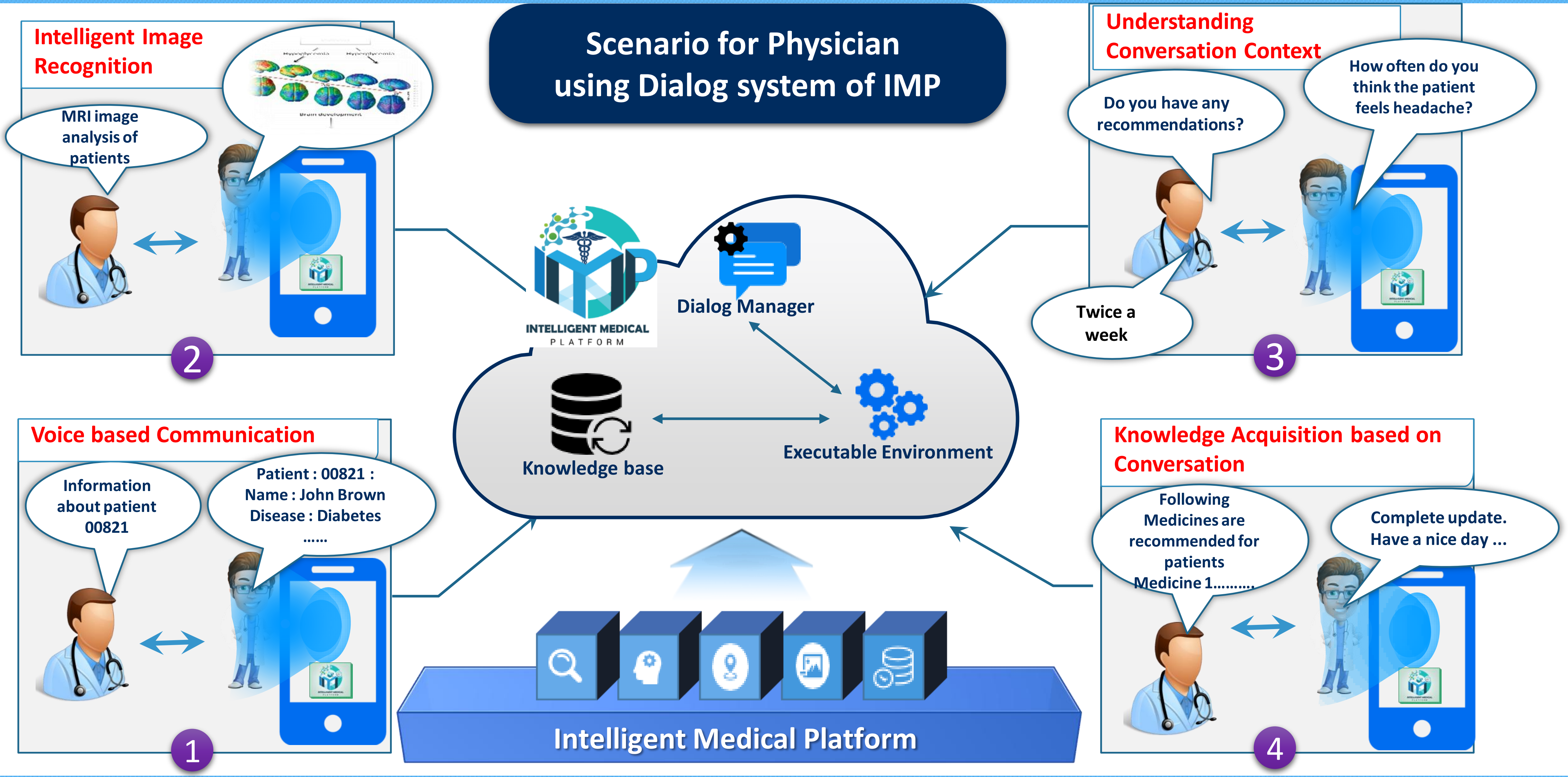
Existing Technology

Uniqueness
- Standardized format conversion

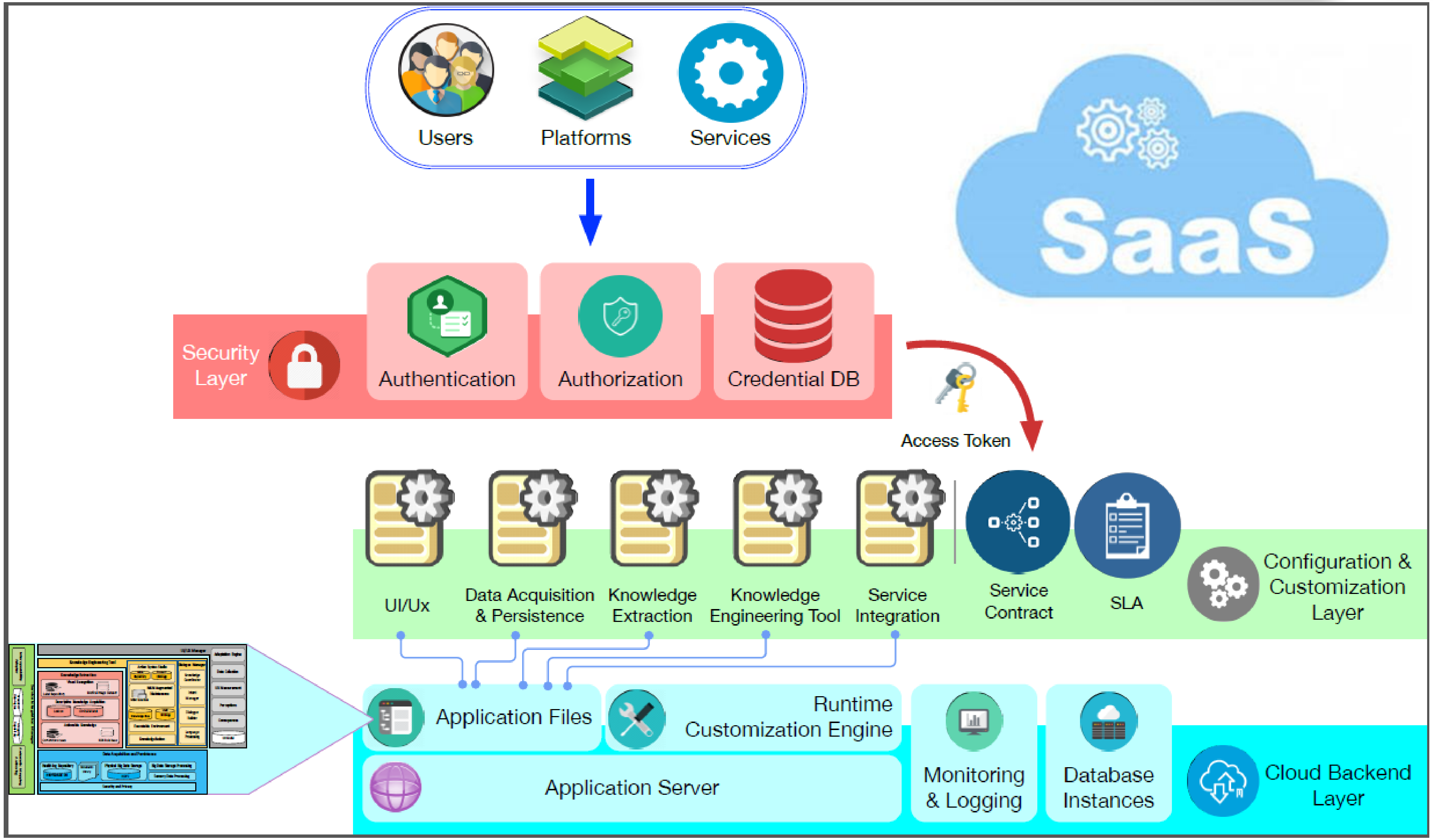


Uniqueness
- Customized mappings generation and evolution

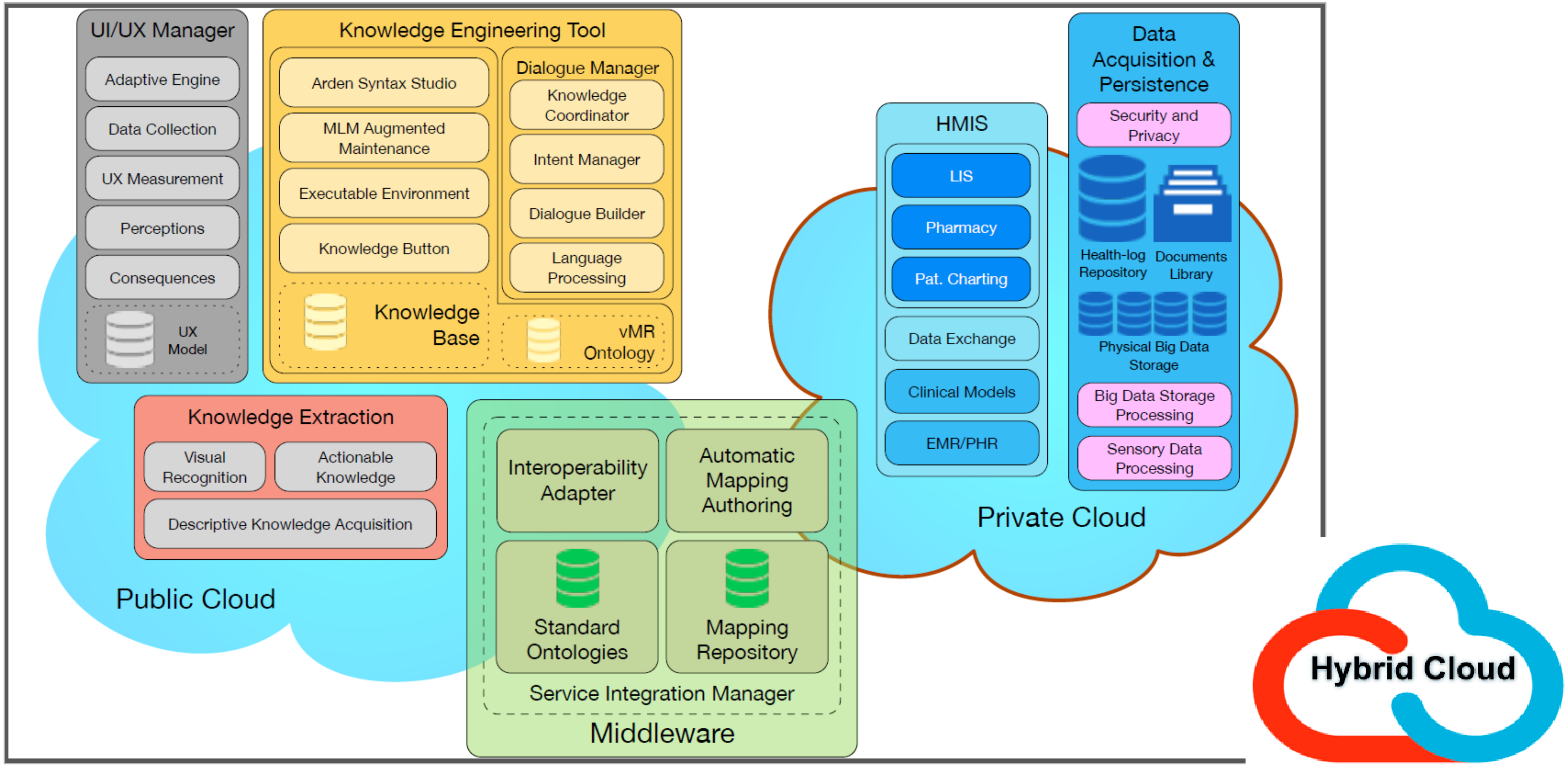
Service Scenario



SaaS Implementation



Deployment over Cloud



Benefits

- Research Initiative for Intelligent Medical Systems and Services
- Promote Collaboration in ICT Medical Convergence

- Triggering Business Innovation with IMP
- Construct Business Ecosystem using Open Source Code

- Construct High Quality of Medical Knowledge Base
- Achieve Medical Innovation by means of Reducing Medical Errors and Cost
- Obtain and Share Clinical Data
- HIS Integration by Standardization

Considering factors for New Generation of Intelligent Medical Platform

- Incremental Knowledge Learning (Expert Driven + Data Driven)
- Engineering Tool Support
- Dialog-based User Interaction
- Cloud Services such as SaaS
- Interoperability in Heterogeneous Resources
- Holistic Approach
- Ethical Issues

Appendix

IMP vs IBM Watson

Proposed IMP vs IBM Watson

Intelligent Medical Platform

Small Data & Human Knowledge Base

- The system use fine-grained knowledge to provide customized services
- Knowledge creation from small and big data with human intervention
- Enriched knowledge technology to make highly accurate knowledge bases for small data
- Combining data and human knowledge, ideal for both generalized and specialized cases
- It also enables knowledge fusion and learning through Dialogue between humans and systems.

IBM Watson

Big data Foundation

- The 4th industry revolution turned to the IoT environment
- Knowledge creation is primarily based on data-driven approaches only
- Data-driven and statistical approaches prone to accuracy and performance degradation
- Generalized knowledge creation, rare cases cannot be considered
- High verification cost in knowledge acquisition and maintenance
- Limited knowledge description results in low level satisfaction

IMP vs IBM Watson

Knowledge-Based Construction Methods

Intelligent Medical Platform

Evolutionary Knowledge Learning

- Learning with the small and big data
- Learned Knowledge can be described with example
- Learned knowledge uses automatic tagging of data, securing high quality data and improving utilization of big data.
- Difficult to make real-time correction of knowledge
- Incremental learning based knowledge evolution
- Automatic verification of knowledge acquisition process

IBM Watson

Deep Learning Knowledge

- Large size data is required
- Cannot explain reason for learned knowledge
- Manual data labelling
- Error in data acquisition results in low accuracy
- Unable to extract new knowledge from existing data
- Knowledge re-learning cannot guarantee the retention of previous knowledge

Thanks

Sungyoung Lee, Kyung Hee University, Korea
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