

# 2021 Workshop on Digital Healthcare and it's Business Model



INTELLIGENT MEDICAL  
PLATFORM

## Human-Inspired AI-Healthcare Platform

August 26, 2021

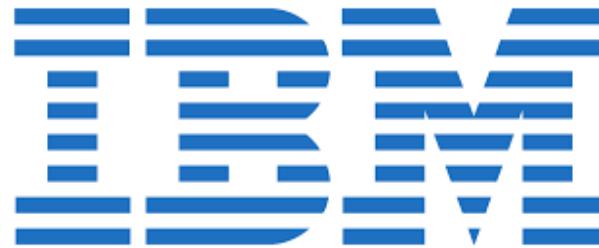
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경희대학교  
KYUNG HEE UNIVERSITY



## The new AI innovation equation



Thought leaders and scientists largely agree on the confluence of forces that have advanced artificial intelligence: the rise of big data, the emergence of powerful GPUs for complex computations and the re-emergence of a decades-old AI computation model—deep learning. **What are the catalysts for the next wave of innovation?**

- ❖ We need to approach AI in a **multidisciplinary way** because the brain itself is a bundle of interdependent elements.”

— Margaret Boden, Cognitive Science Research Professor, University of Sussex



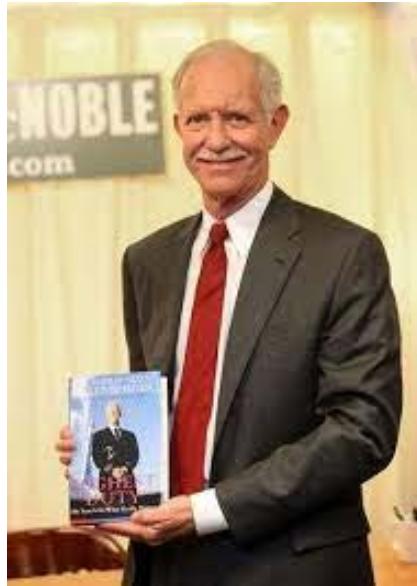
- **Human-like AI: Communicate and Collaborate Seamlessly with Humans**



- Towards more natural, interactive, personalized, and human-inspired AI systems.

- Hybrid Machine Learning for Smart Medical Service

# Example of Human Factors



체슬리 설렌버거

2009년 1월 15일 미국 뉴욕에서 비행기 사고가 발생했다.  
155명을 실은 US항공 소속 비행기가 이륙한 지 얼마 안 돼  
새떼와 부딪혀 양쪽 엔진이 꺼지면서 허드슨강에 비상착수.



연방교통안전위원회(NTSB)의 청문회는 기장의 판단이 옳았는지를 조사한다. 비행기가 라구아디아로 회항하던지, 아니면 티터보로 공항으로 비상착륙을 왜 않았는지를 추궁. 사고 비행기가 이륙해서 비상착수 할 때까지 걸린 시간은 3분 28초

Human Factors-> 35 초 (208초 중)

톰 행크스

2009년 비행기 추락사고 실화  
그 알려지지 않은 이야기



톰 행크스  
설리 허드슨강의 기적

FILMED WITH IMAX® CAMERAS  
WARNER BROS. PICTURES PRESENTS  
IN ASSOCIATION WITH VILLAGE ROADSHOW PICTURES A FEASLIGHT FILMS PRODUCTION A KENNEDY/MARSHALL COMPANY PRODUCTION A MALPASO PRODUCTION  
TOM HANKS "SULLY" AARON ECKHART LAURA LINNEY CHRISTIAN JACOB AND THE TIERNEY SUTTON BAND DEBORAH HOPPER  
BLU MURRAY JAMES J. MURAKAMI TOM STREETER A.F.C. JESSICA MEIER KRISTINA RIVERA  
PRODUCED BY KIPP NELSON AND BRUCE BERMAN CHESLEY "SULLY" SULLENBERGER AND JEFFREY ZASLOW  
WRITTEN BY TODD KOMARNICKI DIRECTED BY FRANK MARSHALL EDITED BY ALLYN STEWART PROD. DESIGNER TIM MOORE  
DIRECTOR OF PHOTOGRAPHY CLINT EASTWOOD

9월 대개봉



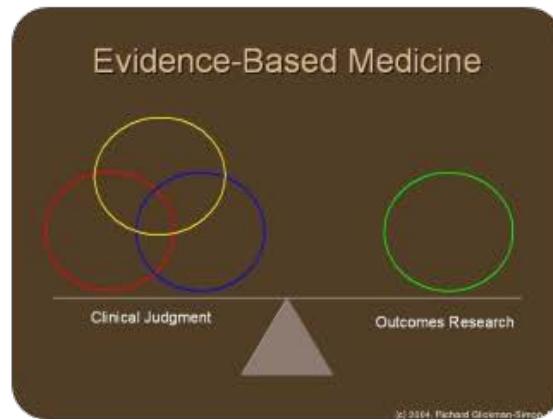
## 사회 요구

## 해결 방법

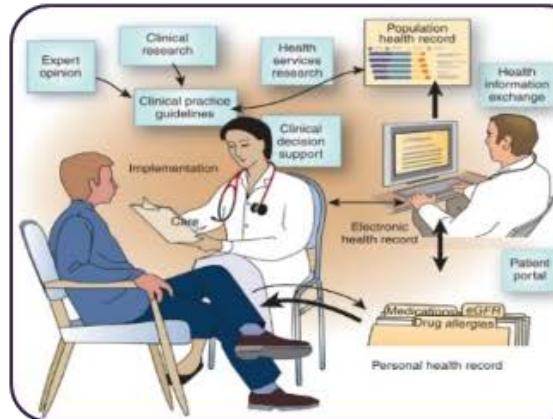
## 기대효과

- 의료 질 향상
- 지식의 데이터화
- 환자 진료기록

CDSS



의사결정 지원



임상진료 지침

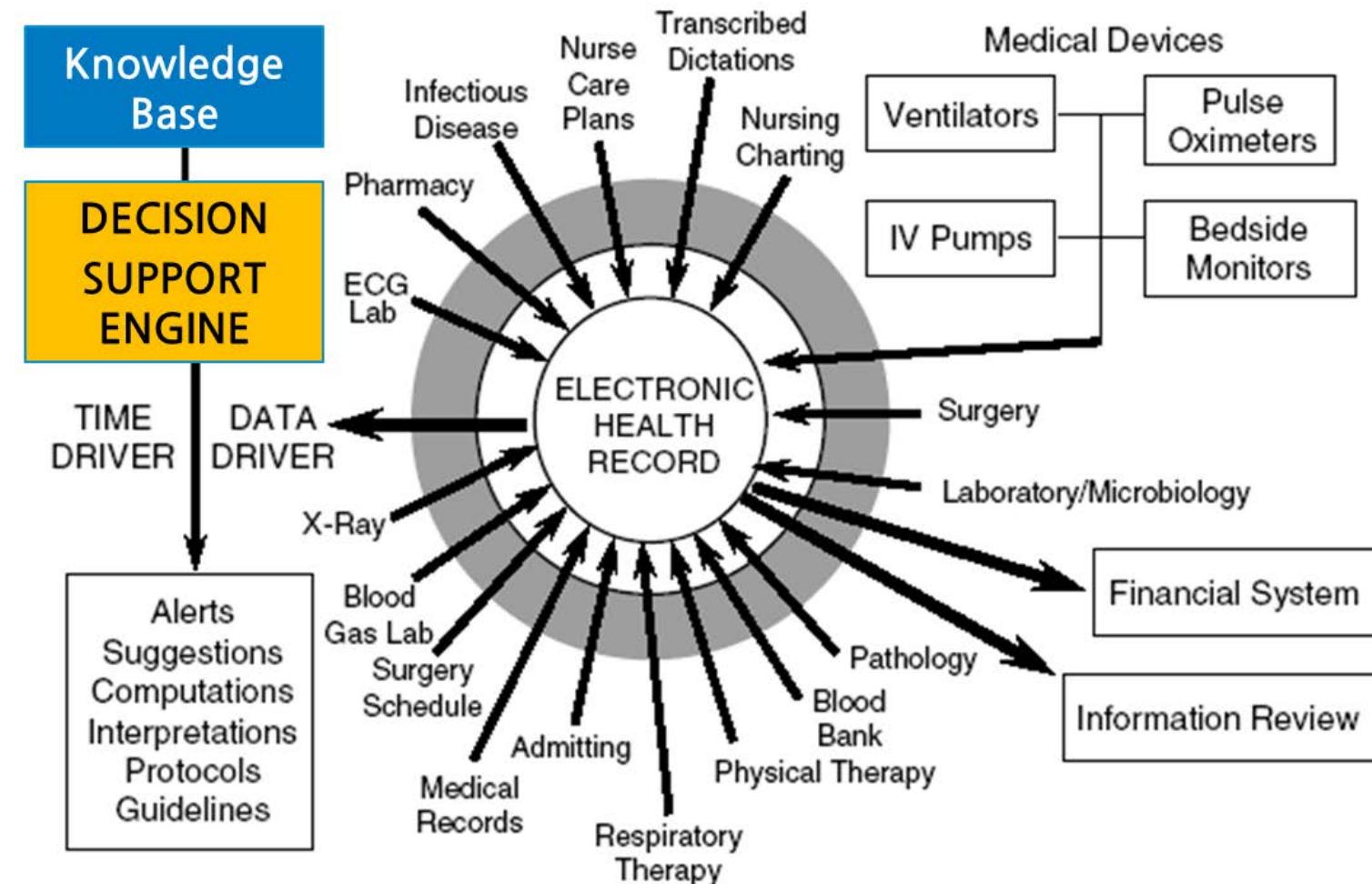


의료 서비스 전달 효율성



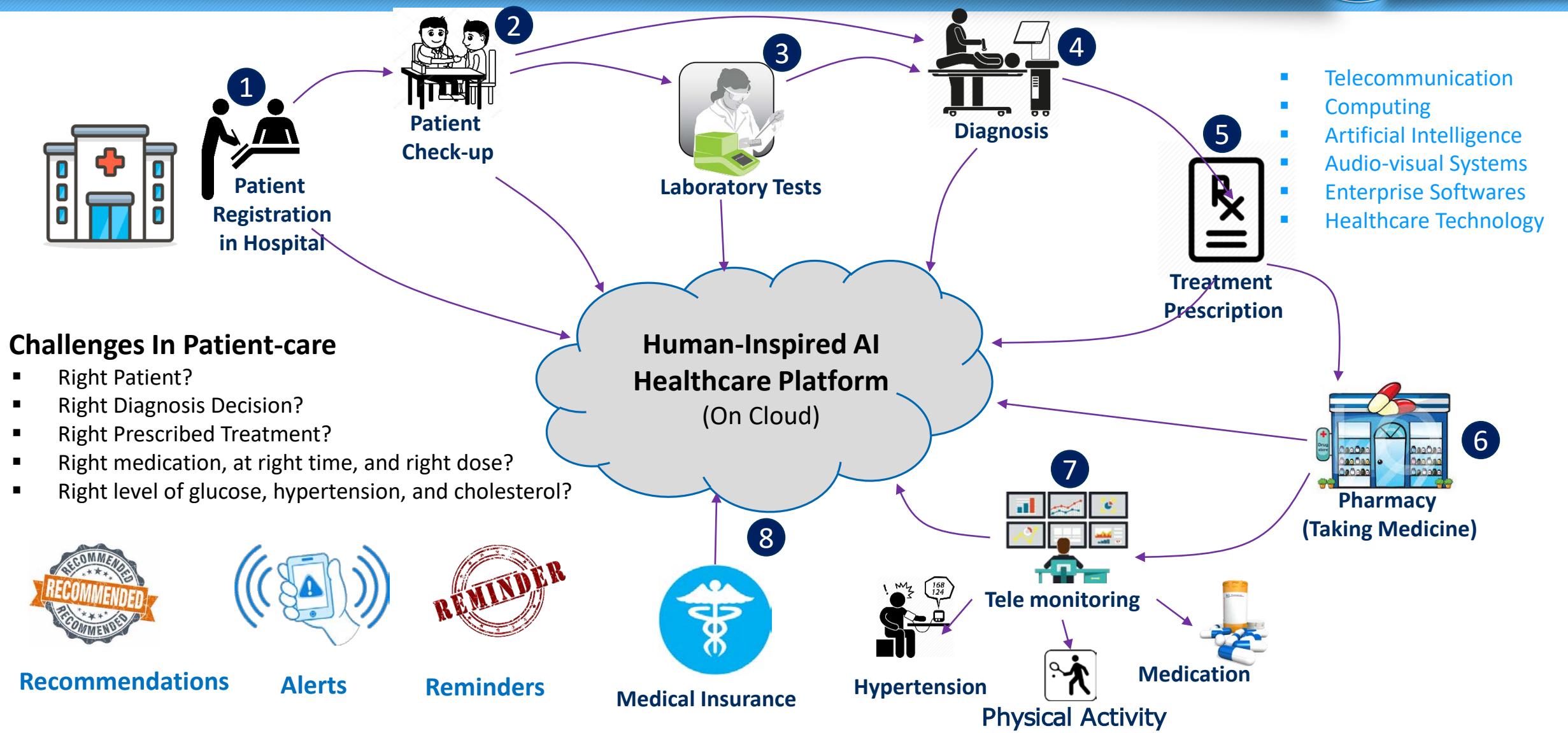
환자 안정성

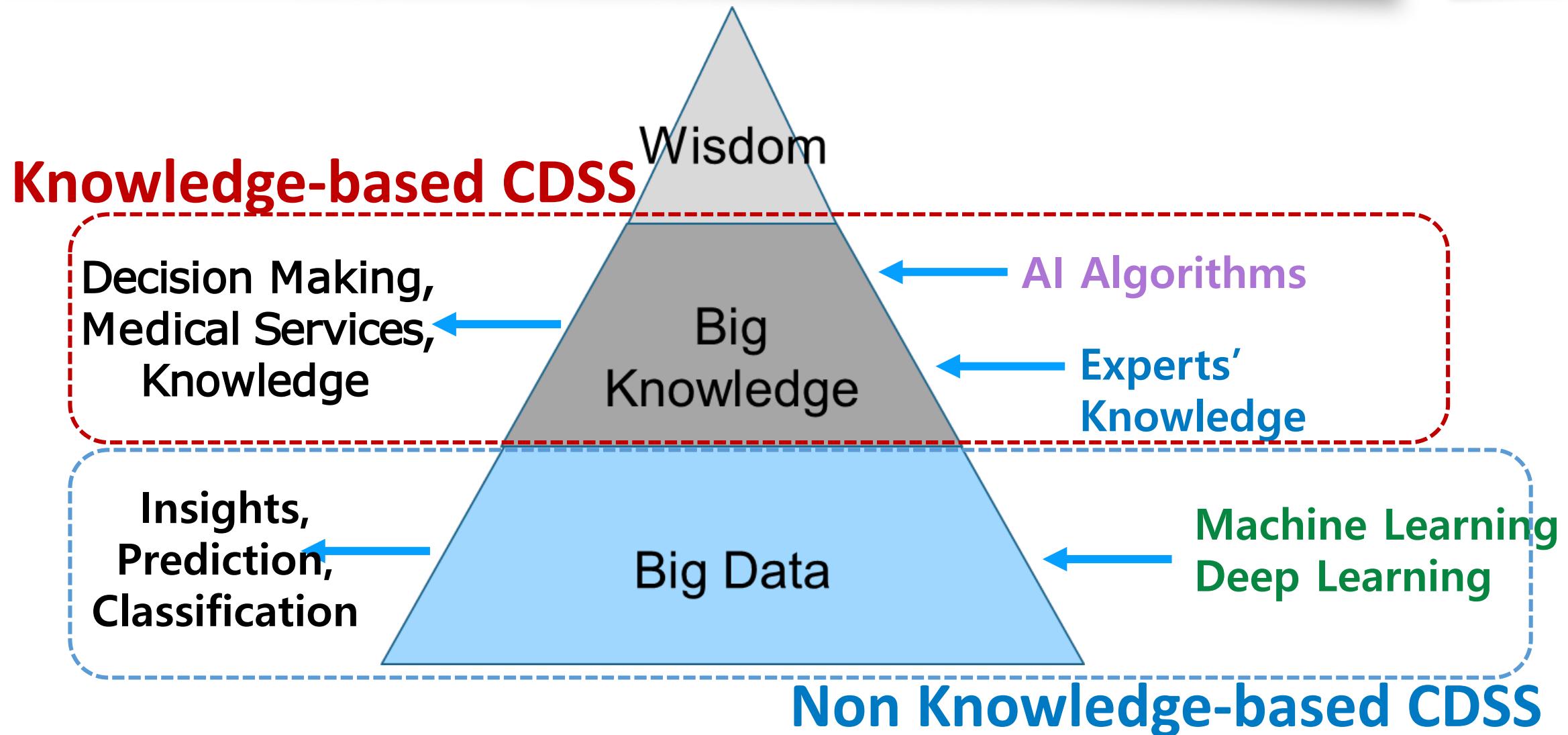
# General Structure of CDSS



※ CDSS의 핵심은 DECISION SUPPORT ENGINE의 **지식획득 및 지식 관리 기술**

# Echo Systems of Medical Decision Support





# Requirements of Big Dataset on Deep Learning

FACTOR	DESCRIPTION
<b>DL Challenge</b>	Supervised or Unsupervised, Classification or Regression, # of labels?
<b>Architecture</b>	What is the simplest architecture that I can use?
<b>Training Model</b>	How am I going to tune my neural network? Kinds of non-linearity, loss function and weight initialization? Best training framework?
<b>Data Quantity</b>	How much data will be sufficient to train my model? How do I go about finding that data and is it evenly balanced?
<b>Data Quality</b>	Is my data directly relevant to the problem & real-world data.
<b>Data Labels</b>	Is my training data is labeled same as raw datasets, how do I “featurize”?
<b>Data Similarity</b>	Is data same length vectors or does it require pre-processing?
<b>Data Storage &amp; Access</b>	Where is it stored, locally and on network Data pipeline? How do I plan to extract, transform, and load the data (ETL)?
<b>Infrastructure</b>	Cloud, On premise, Hybrid. GPUs, CPUs, or both? Single or distributed systems? Integration with languages, ent. apps/databases.



서울아산병원  
Asan Medical Center



## [닥터 앤서 – 2020년까지 개발]

- AI의료데이터 통합 및 연계 기술 개발
- 19개 ICT/SW 기업 참여 (데이터 스트림즈, 뷰노, 제이엘케이 인스펙션, 카카오브레인 등) 8개 질환 (유방암, 대장암, 전립선 암, 심뇌혈관질환, 심장질환, 뇌전증, 치매, 소아 희귀난치성 유전질환) 인공지능 의료 SW

VUNO



## [뷰노메드 본 에이지]

- 성조숙증이나 저신장증을 진단하기 위해 촬영된 엑스레이를 AI가 자동으로 분석하고 의사의 판별을 도움을 주는 지원 SW
- 식약처로부터 인증받아 의료영상 분석 소프트웨어 2등급 허가서를 취득함

Lunit



## [폐질환 감별 AI 소프트웨어]

- 의료 영상 정보를 기반으로 폐암과 폐렴, 기흉, 결핵 등 4대 폐질환을 판독하는 SW (정확도: 90%)
- 현재 서울 삼성병원과 MOU 체결하여 진단 보조시스템을 구축하고 임상실험 진행 중

JLK INSPECTION



## [AI Medical Solution]

- MR 이미지 및 심방세동 (AF) 정보를 기반으로 뇌졸증을 진단하는 AI 의료 시스템
- 현재 식품 의약청의 3등급 의료기기 허가서를 취득함

## AI Programs

### Knowledge Base Systems

#### Expert Systems

- Apply expert knowledge to difficult, Real world problems
- Make domain knowledge Explicit
- Exhibit Intelligent Behavior by skillful application of heuristics





## Clinical Decision Support in the Era of Artificial Intelligence

**Edward H. Shortliffe, MD, PhD** (*Biomedical Informatics, Columbia University, New York, New York, Biomedical Informatics, Arizona State University, Phoenix*); **Martin J. Sepúlveda, MD, ScD** (*Retired from IBM Research, Watson Research Laboratory, Yorktown Heights, New York*), December 4, 2018 Volume 320, Number 21, **JAMA**

Why, then, do clinical decision support systems (CDSSs) designed for direct interactive use by clinicians have challenges of credibility and adoption when the literature has been replete for 4 decades with studies that present computing systems demonstrating diagnostic accuracy that rivals the performance of expert clinicians? The reasons are varied and reflect the realities and complexities of clinical practice. Biomedical informaticians have long understood those reasons, recognizing the spectrum of capabilities and characteristics that must be incorporated into a CDSS if it is to be accepted and integrated into routine workflow:

- **Black boxes are unacceptable:** A CDSS requires transparency so that users can understand the basis for any advice or recommendations that are offered.
- **Time is a scarce resource:** A CDSS should be efficient in terms of time requirements and must blend into the workflow of the busy clinical environment.
- **Complexity and lack of usability thwart use:** A CDSS should be intuitive and simple to learn and use so that major training is not required and it is easy to obtain advice or analytic results.
- **Relevance and insight are essential:** A CDSS should reflect an understanding of the pertinent domain and the kinds of questions with which clinicians are likely to want assistance.
- **Delivery of knowledge and information must be respectful:** A CDSS should offer advice in a way that recognizes the expertise of the user, making it clear that it is designed to inform and assist but not to replace a clinician.
- **Scientific foundation must be strong:** A CDSS should have rigorous, peer-reviewed scientific evidence establishing its safety, validity, reproducibility, usability, and reliability



## 문제점

transparency



Big Wisdom



Big Knowledge

Big Data



투명성, 지식품질, 유지보수

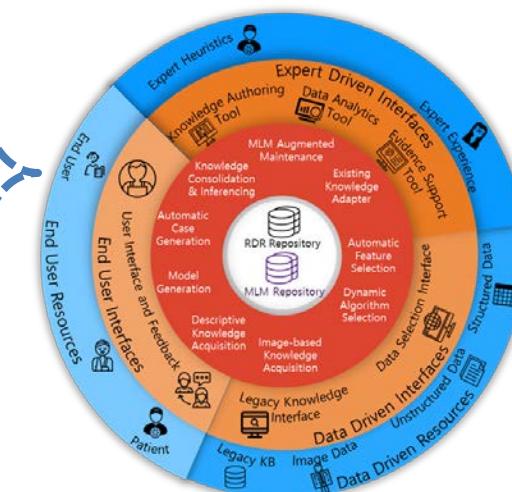
## Data Driven: Black Box



## Expert Driven: White Box

## 해결 방법

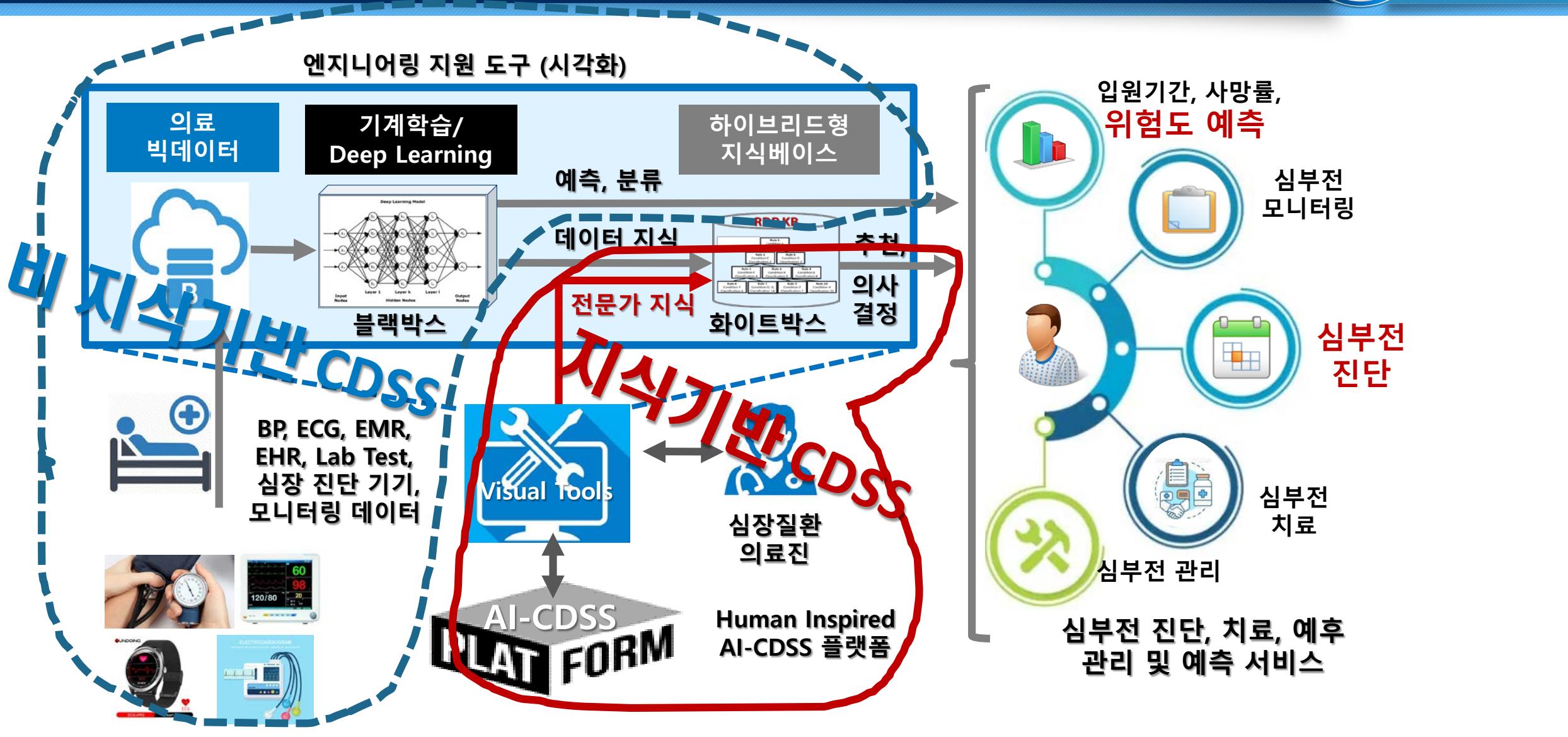
- White box 기반(투명성)
- 하이브리드형(품질)
- 점진적 지식진화(RDR)모델(유지보수)



멀티모달 기반  
지식 플랫폼



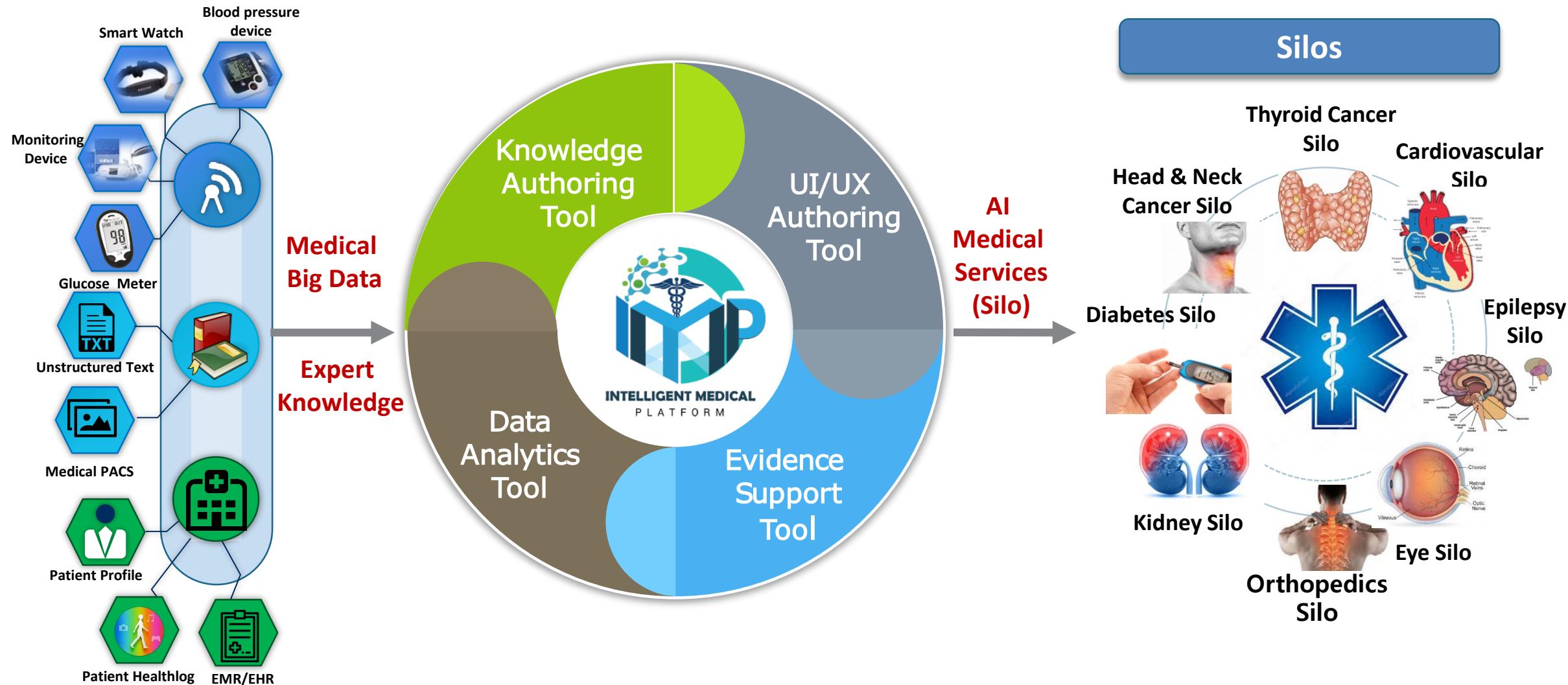
엔지니어링  
지원 도구



# Research Overview



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# How to Hybridizing?

## 입력 데이터

### 1 텍스트 데이터

#### 의사 노트

- 등록시
- 입원시

#### 간호사 노트

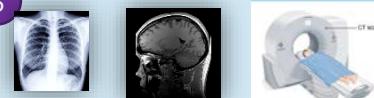
- 등록시
- 입원시

### 2 숫자 데이터

#### 랩 테스트 결과 생체신호기록

- 등록시
- 입원시

### 3 이미지/동영상



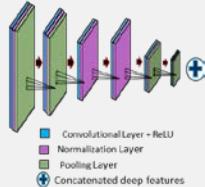
심초음파, ECG, MRI

### 4 의사 계획 및 지식

- 현장 경험
- 의료 지식
- 계획

## 적용 모델-AI 알고리즘

### 딥러닝 및 머신러닝



### 심부전 레이블

- Disease = HFrEF
- LVEF = 543.96
- TRV = 365.6
- RA/RV Anomaly

#### AI 처리: 자연어 처리

텍스트 전처리

탐색 데이터 분석

특징 엔지니어링

패턴 마이닝

### 화이트박스 머신러닝 알고리즘

#### 데이터 전처리

- 데이터 임пут레이션
- 데이터 이산화
- 데이터 정규화

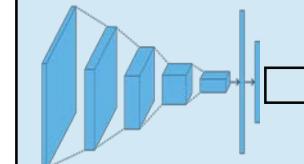
#### 특징 추출

- 특징 스코어링
- 임계 간선택
- 서브 셋 선택

#### 화이트박스 ML

- 의사결정트리
- 랜덤포레스트
- J48

### 딥러닝 및 머신러닝



- 정상
- 비정상
- LA/LV Anomaly
- RA/RV Anomaly

- 챔버 볼륨
- Arteries/Veins
- LA/LV Anomaly
- RA/RV Anomaly

### 전문가 기반 지식: 전문가 경험, 허리스틱, 지식

지식 생성

지식 변환

지식 검증

## 서비스 출력

### 입원기간, 위험도, 사망률 등 예측



### 심부전 모니터링

### 심부전 진단

### 심부전 치료

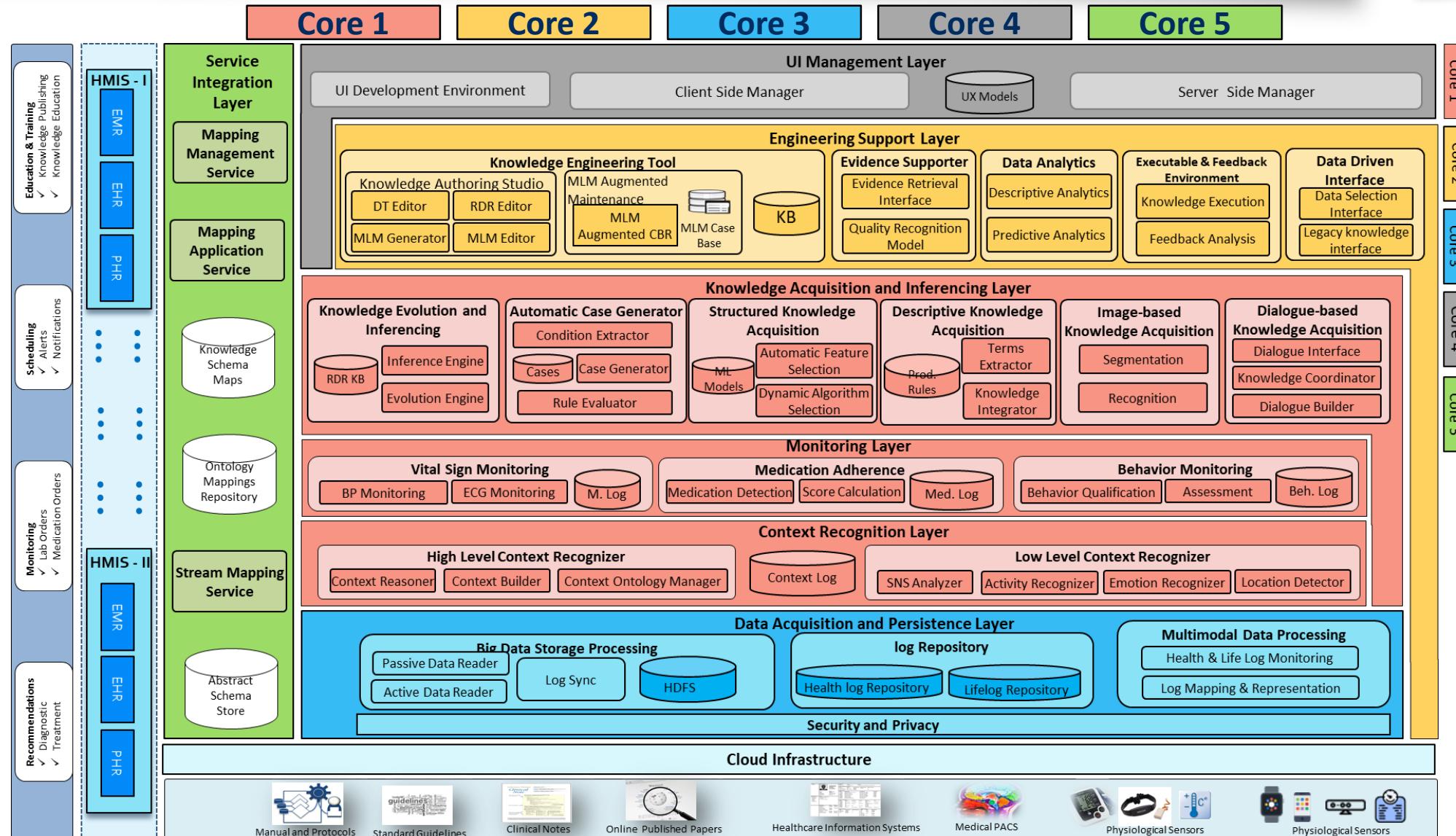
### 심부전 관리

### 지식 병합

# Architecture of HI AI-CDSS Platform



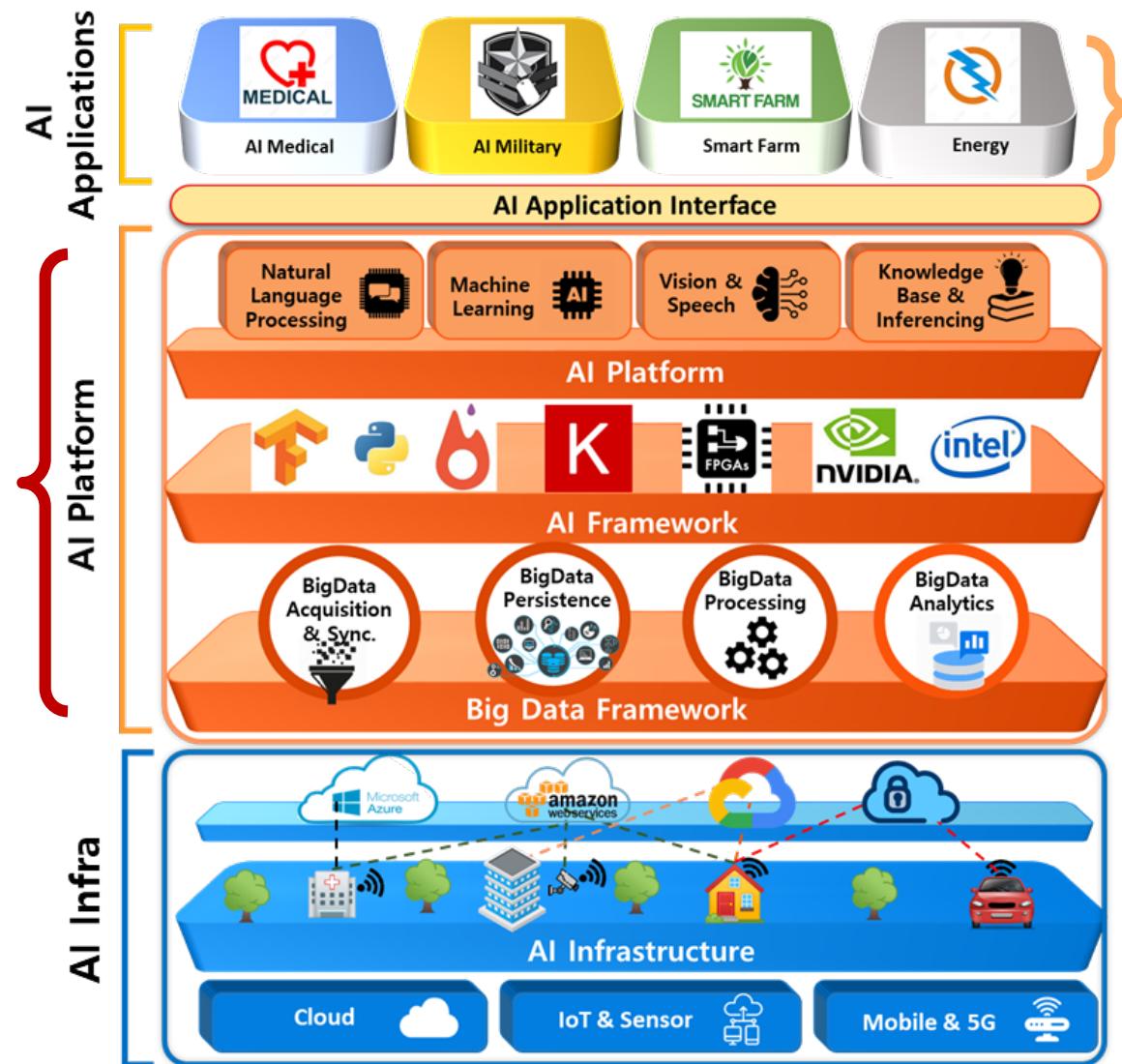
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# Echo Environments of AI Platform



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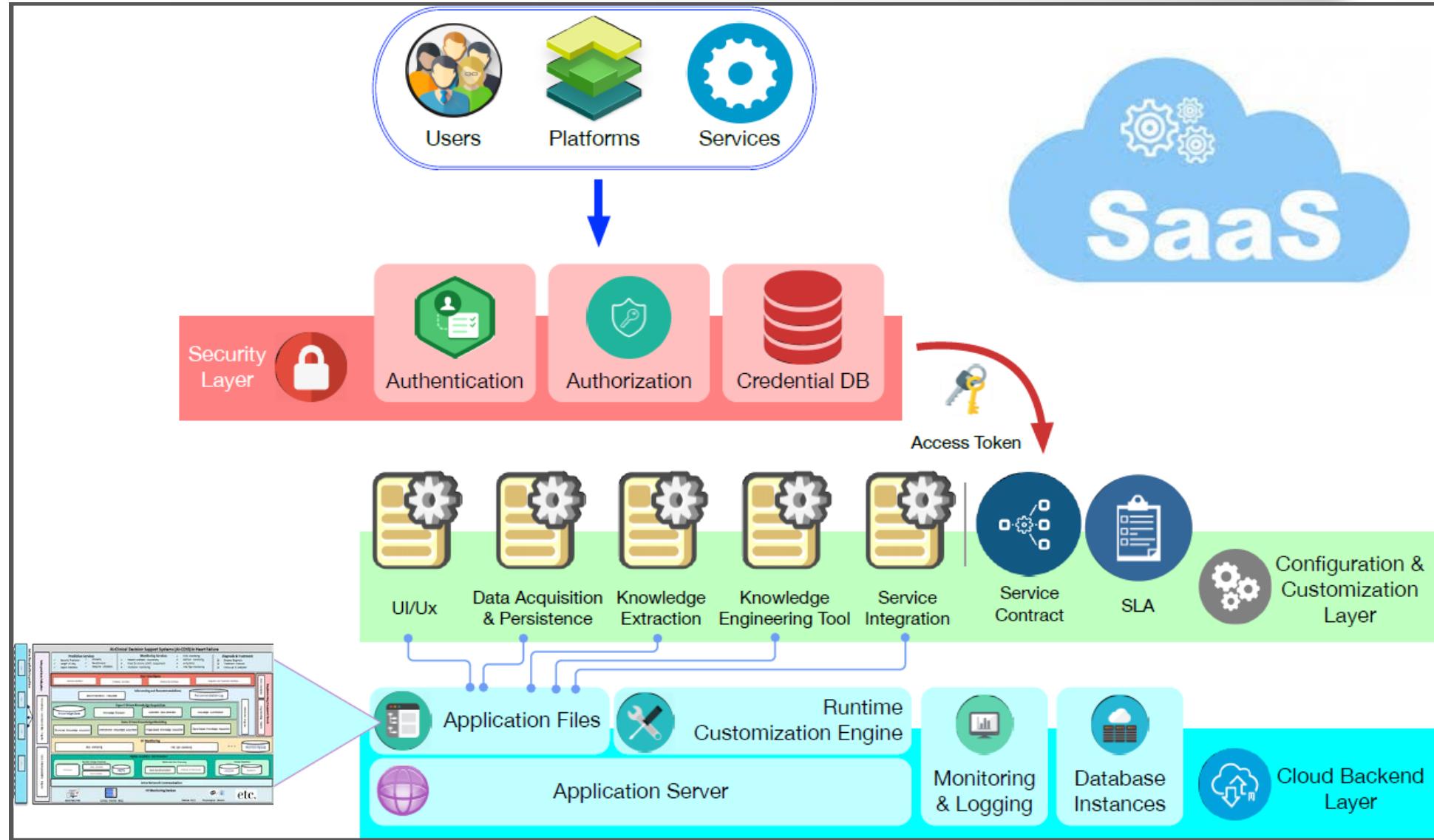
## Applications



# Deploy Components over Cloud by SaaS



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# IMP platform Benefits over Independent Applications



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## Limitation of Independent App



Limitation of Processing, Expensive Devices, Prone to bottleneck



Limited to explicit device and data structure format



Lack of Customization of available resources



Limited Access to the available resources



Rigid connection of devices and web services



## Benefits of IMP



Scalability



Generalization



Adaptability



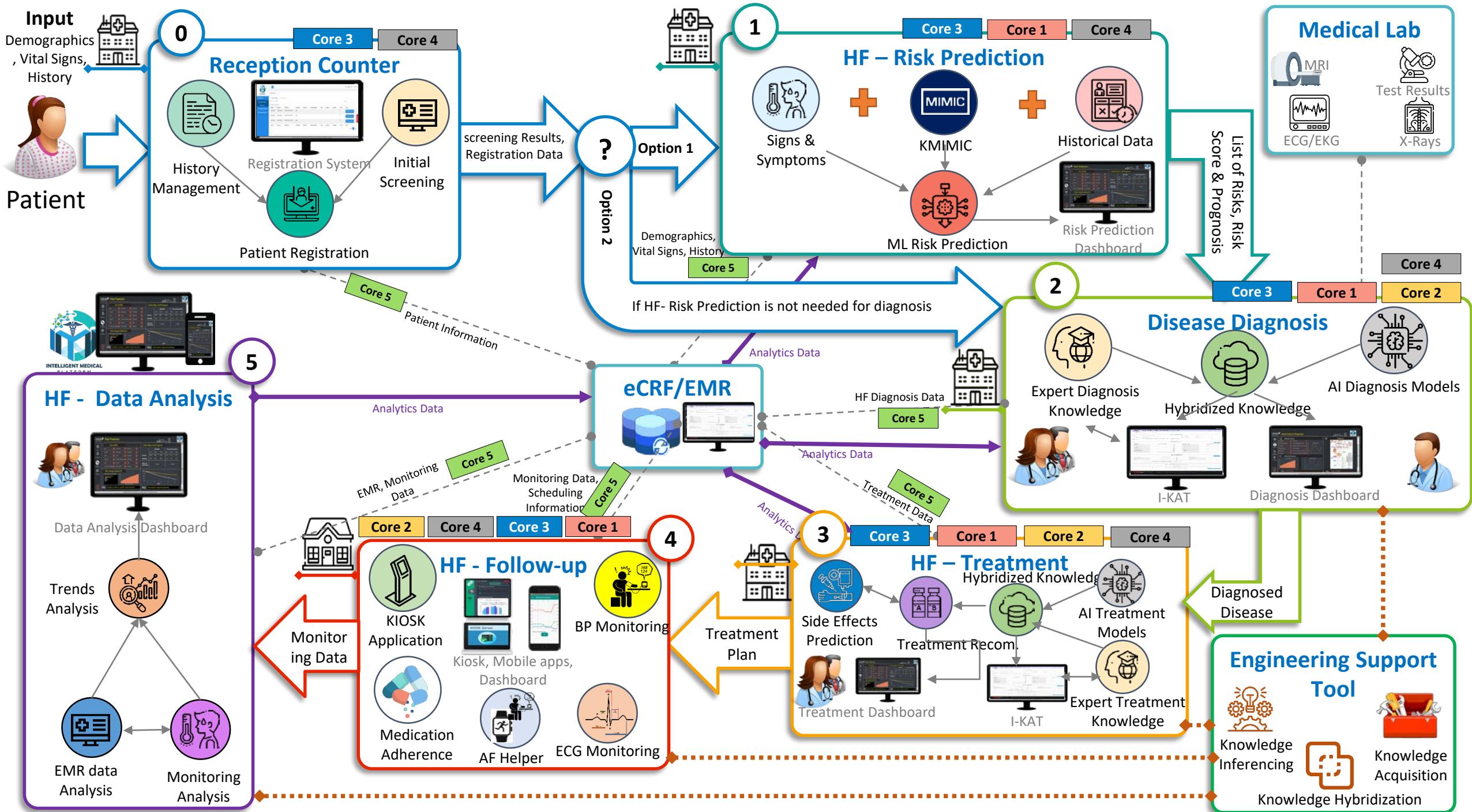
Accessibility



Flexibility



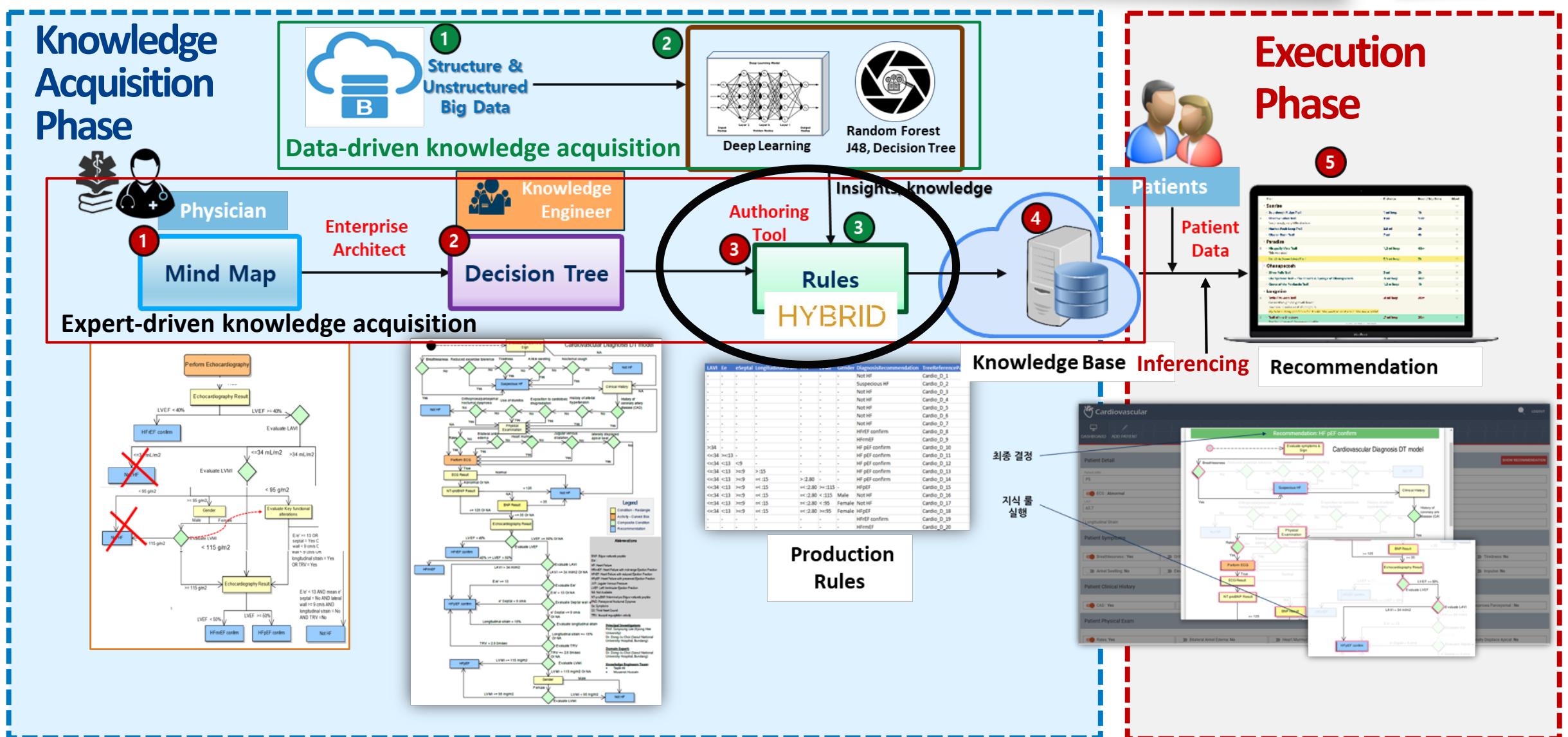
# Case Studies



# Process of Knowledge Acquisition and Execution



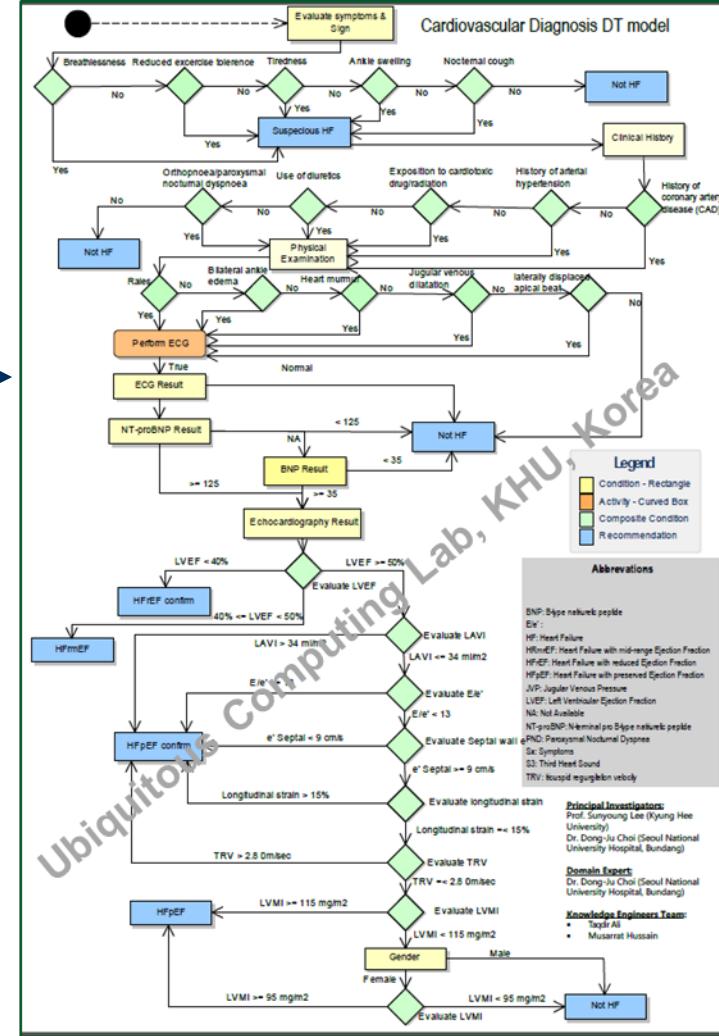
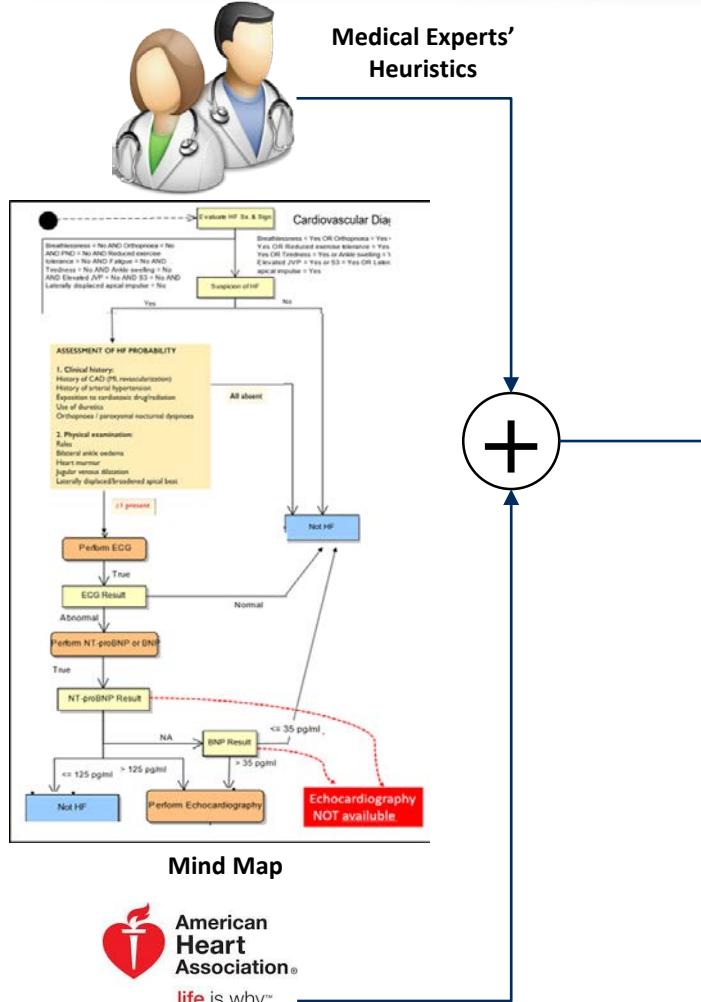
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# Contributing Factors



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## 기여 요인 (심부전 진단)

- P4 ECG Result**
- P5 NT-proBNP Result**
- P6 BNP Result**
- P7 LVEF**  
(Left Ventricular Ejection Fraction)
- P8 LAVI**  
(Left Atrial Volume Index)
- P9 E/e'**
- P10 e' Septal**
- P11 Longitudinal strain**
- P12 TRV**  
(Tricuspid Regurgitation Velocity)
- P13 LVMI**  
(Left Ventricular Mass Index)
- P14 Gender**

- P1**
- 징후 및 증상
    - 가쁜 숨
    - 운동 내구력
    - 피로
    - 발목 붓기
    - 약행성 기침

- P2**
- 병력
    - 관절환 (CAD)
    - 동맥성 고혈압
    - 심장 독성 약물/방사선 노출
    - 좌위 호흡

- P3**
- 신체 검사
    - 수포음
    - 양측 발목 부종
    - 심장 잡음
    - Jugular venous dilatation
    - laterally displaced apical beat

# Knowledge Base Modeling based on Data



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## 기여 요인 (심부전 진단)

A screenshot of the Microsoft Project application. The main view displays a Gantt chart with multiple tasks listed along the horizontal axis and time periods along the vertical axis. Each task is represented by a colored bar indicating its duration and progress. Below the Gantt chart, there is a detailed resource assignment table. On the left side of the screen, there is a navigation pane with various project management icons. The ribbon menu at the top includes tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, and View.

EMR/HMIS

ID	Age	Gender	Symptoms & Sign (If 1 or more=1, NO=0)	Clinical History (If 1 or more=1, NO=0)	Physical Exam (If 1 or more=1, NO=0)	ECG (normal=0, abnormal=1)	NT-proBNP	BNP	LVEF	LAVI	LVMI	E/e'	e' septal	TRV	Longitudinal strain(GLS)
10611919	79	M	1	0	0	0	185.3		59.38	26.37		7.38	6.1	2.5	
11066473	63	M	1	1	0	0	209		65.66	28.89	62.01	8.31	6.74		
11264619	41	F	0	0	0	0	327.8		61.54	23.67	83.4	6.1	10.82	14.5	
13401793	82	M	1	0	0	1	185.4		60.98		90.96	6.54	8.1		19.3
15072850	82	M		1	1	0	177.2		55		54.78	5.32	9.4		
16805356	71	M	1	0	1	1	380.2		52.94		102.4	5.89	10.7	2.5	16.6
18411764	26	M	1	1	0	1	203.4		65.75	18.08	86.07	5.08	11.8		12
20659893	83	F	1	1	1	0	156.2		60.56	33.09	82.15	11.25	4.8	2.6	
26190107	78	F	1	0	0	0	201.6		56.1	31.54	83.92	10.44	4.5	2.6	18
26289425	34	F	1	1	0	1	1447.6		55.56	33.56	67.11	7.89	12.3	2.3	
27645097	84	M	1	1	0	0	164.6		62.5	33.89	95.64	12.24	6.7	2.8	
27691432	68	M	1	0	0	0	321.6		65.38		65.57	6.87	8.3	2.7	20.3

## 환자 데이터셋: 1000

 rapidminer

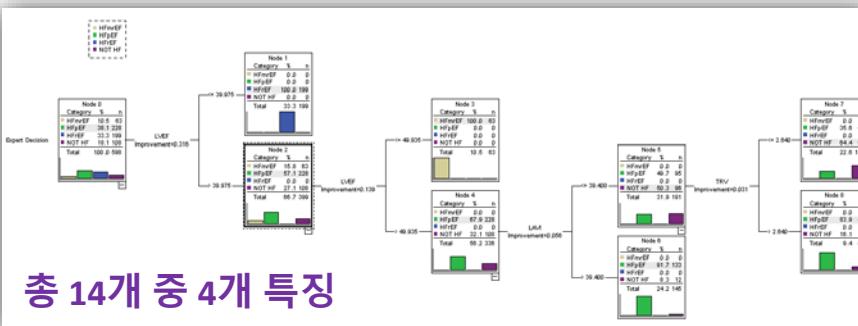
# 기계학습 알고리즘

블랙박스 알고리즘

- Naïve Bayes = 77%
  - Generalized Linear Model = 74%
  - Deep Learning = 80%

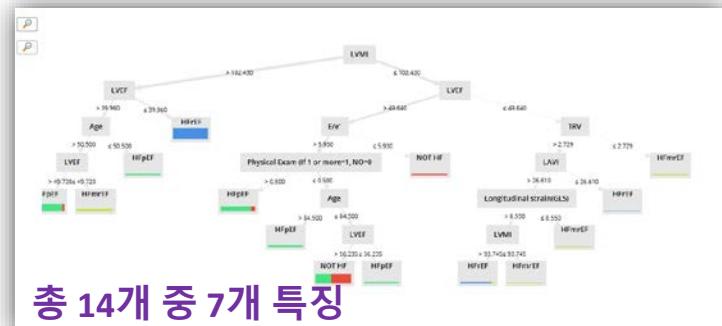
## 화이트박스 알고리즘

CRT with 88.55%



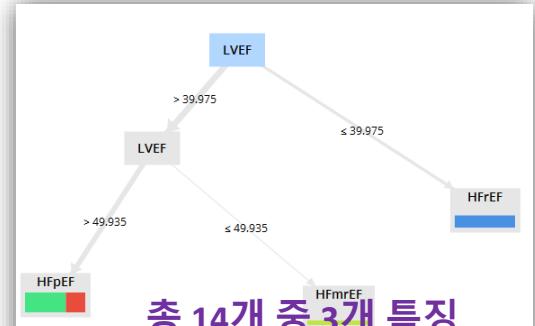
## 총 14개 중 4개 특징

## Random Forest with 86%



총 14개 중 7개 특징

## Decision Tree with 82%



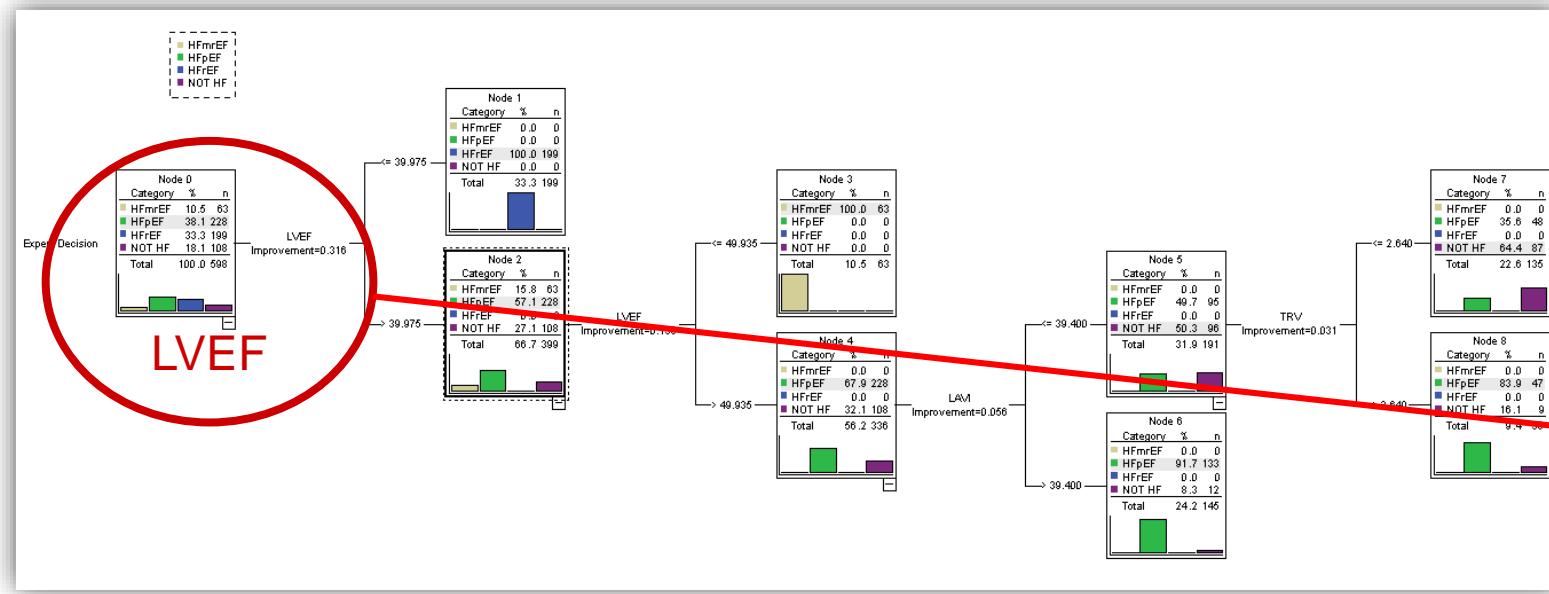
HFmrEF

# Construction of Hybrid Knowledge



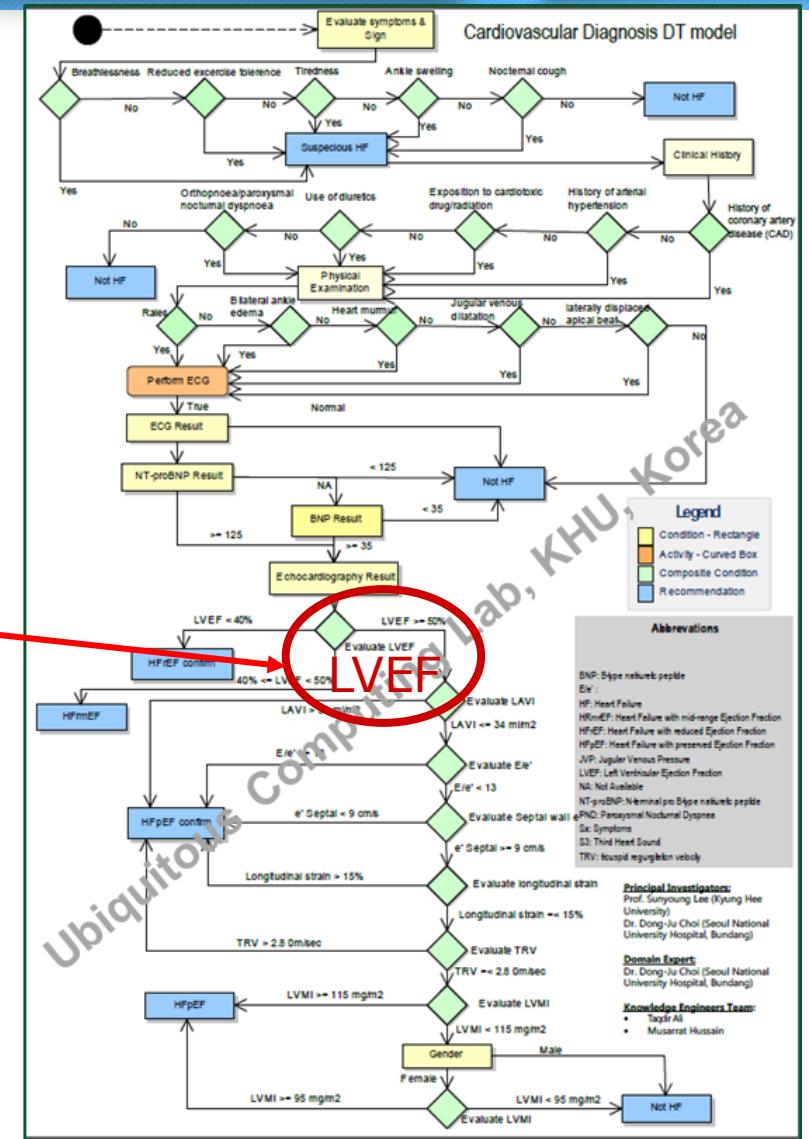
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예측 모델은 LVEF로 시작하며, IDT는 중간에 LVED를 가짐



## 결과:

IDT는 LVEF에 도달하기 위해 null값 경로가 요구됨 (Conformance)

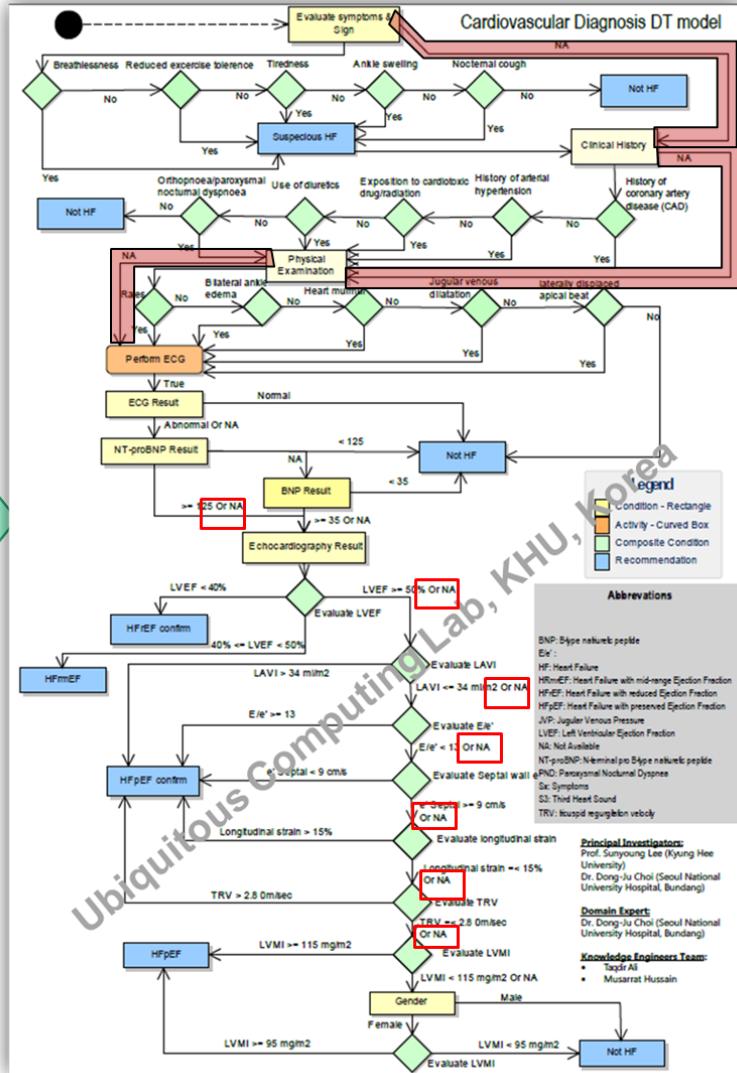


# After Hybridizing based on White box Model



28

## 의사 결정 트리



의료 전문가

## Intelligent Knowledge Authoring Tool (iKAT)



## 생산 규칙

Rule #	RuleTitle	SymptomsAndSigns	ClinicalHistory	PhysicalExam	ECG	NTproBNP	BNP	LVEF
1	CardiovascularRule-1	0 -	-	-	-	-	-	-
2	CardiovasulerRule-2	1 -	-	-	-	-	-	-
3	CardiovasulerRule-3	1 0 -	-	-	-	-	-	-
4	CardiovasulerRule-4	1 1 0 -	0 -	-	-	-	-	-
5	CardiovasulerRule-5	1 1 1 0 -	1 0 -	-	-	-	-	-
6	CardiovasulerRule-6	1 1 1 1 <:125 -	1 <:125 -	-	-	-	-	-
7	CardiovasulerRule-7	1 1 1 1 -	1 -	< :35 -	-	-	-	-
8	CardiovasulerRule-8	1 1 1 1 -	1 -	>=:35 <:40	-	-	-	-
9	CardiovasulerRule-9	1 1 1 1 -	1 -	>=:35 () :39 & 50	-	-	-	-
10	CardiovasulerRule-10	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
11	CardiovasulerRule-11	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
12	CardiovasulerRule-12	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
13	CardiovasulerRule-13	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
14	CardiovasulerRule-14	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
15	CardiovasulerRule-15	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
16	CardiovasulerRule-16	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
17	CardiovasulerRule-17	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
18	CardiovasulerRule-18	1 1 1 1 -	1 -	>=:35 >=:50	-	-	-	-
19	CardiovasulerRule-19	1 1 1 1 -	1 -	>=:125 -	< :40	-	-	-
20	CardiovasulerRule-20	1 1 1 1 >=:125 -	1 >=:125 -	( ) :39 & 50	-	-	-	-
21	CardiovasulerRule-21	1 1 1 1 -	1 -	>=:125 -	-	>=:50	-	-
22	CardiovasulerRule-22	1 1 1 1 -	1 -	>=:125 -	-	>=:50	-	-
23	CardiovasulerRule-23	1 1 1 1 -	1 -	>=:125 -	-	>=:50	-	-
24	CardiovasulerRule-24	1 1 1 1 -	1 -	>=:125 -	-	>=:50	-	-

LAVI	Ee	eSeptal	LongitudinalStrain	TRV	LVMI	Gender	DiagnosisRecommendation	TreeReferencePath
-	-	-	-	-	-	-	Not HF	Cardio_D_1
-	-	-	-	-	-	-	Suspicious HF	Cardio_D_2
-	-	-	-	-	-	-	Not HF	Cardio_D_3
-	-	-	-	-	-	-	Not HF	Cardio_D_4
-	-	-	-	-	-	-	Not HF	Cardio_D_5
-	-	-	-	-	-	-	Not HF	Cardio_D_6
-	-	-	-	-	-	-	Not HF	Cardio_D_7
-	-	-	-	-	-	-	HFrEF confirm	Cardio_D_8
-	-	-	-	-	-	-	HFrEF	Cardio_D_9
-	-	-	-	-	-	-	HpEF confirm	Cardio_D_10
-	-	-	-	-	-	-	HpEF	Cardio_D_11
-	-	-	-	-	-	-	HpEF confirm	Cardio_D_12
-	-	-	-	-	-	-	HpEF confirm	Cardio_D_13
-	-	-	-	-	-	-	HpEF confirm	Cardio_D_14
-	-	-	-	-	-	-	HpEF	Cardio_D_15
-	-	-	-	-	-	-	HpEF	Cardio_D_16
-	-	-	-	-	-	Male	Not HF	Cardio_D_17
-	-	-	-	-	-	Female	Not HF	Cardio_D_18
-	-	-	-	-	-	-	HFrEF confirm	Cardio_D_19
-	-	-	-	-	-	-	HFrEF	Cardio_D_20

총 규칙 개수: 15409  
 총 환자 데이터 : 600  
 최종 정확도 : 98.3%

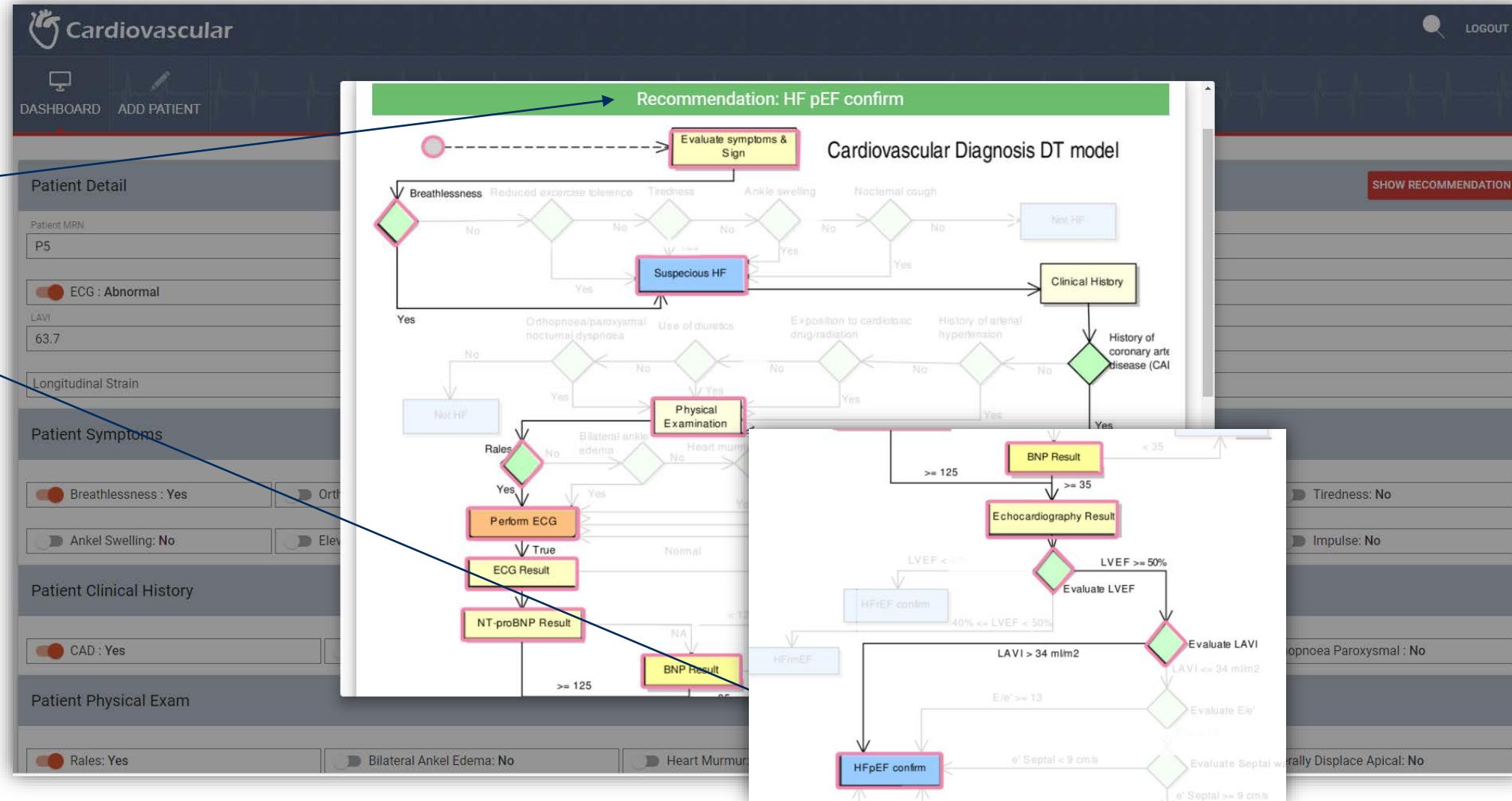
# Intervention of Recommendation



29

**추천:** 환자의 프로필과 증상에 따라 권고 사항 제공 (의사결정은 지식베이스로부터 생성)

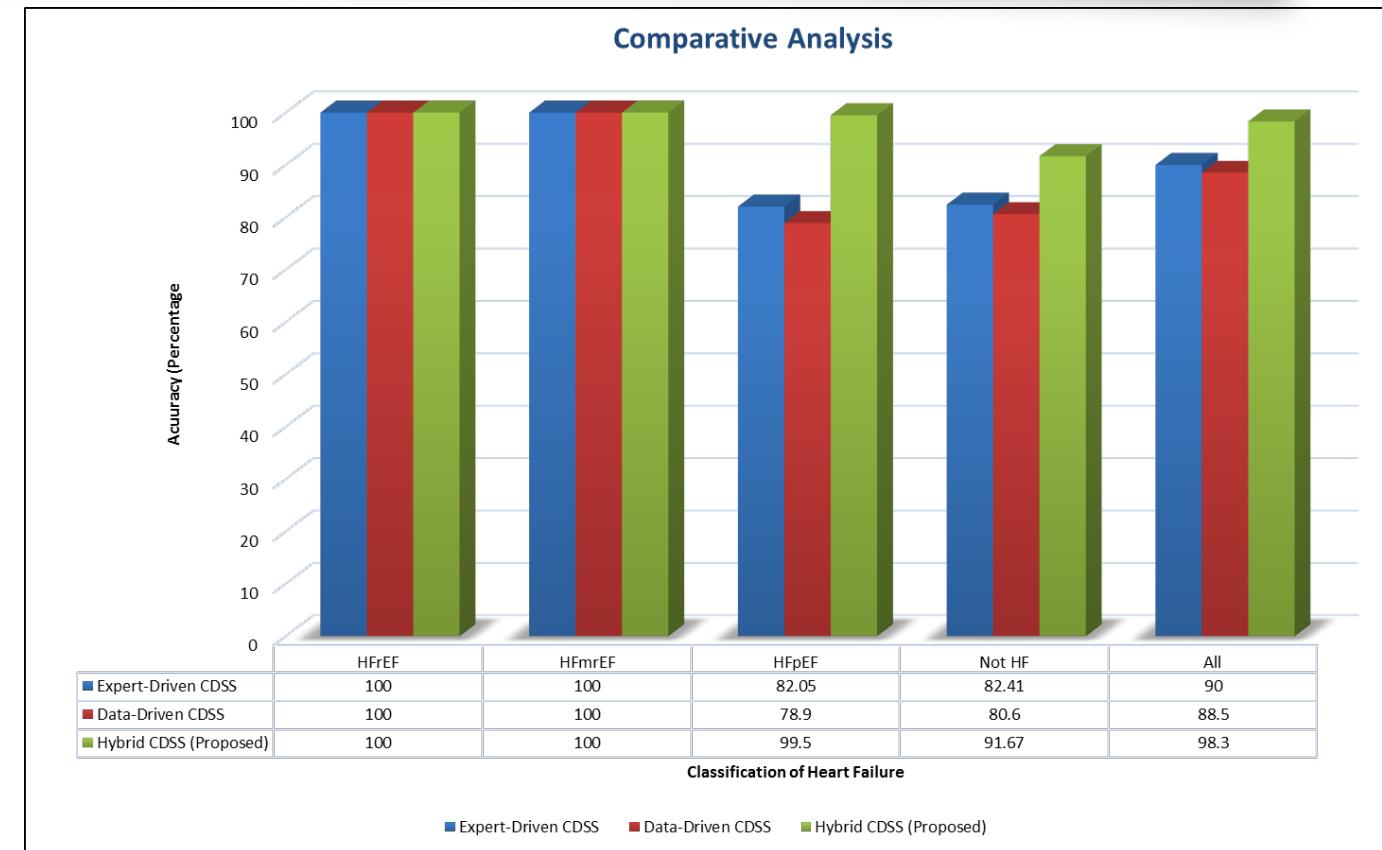
최종  
의사결정  
  
지식 규칙  
실행





## 전체 정확도

- 하이브리드 (98.3%)
- 전문가 기반 (90%)
- 데이터 기반 (88.5%)



최동주, 이승룡 외, "Artificial intelligence for the diagnosis of heart failure", Nature Partner Journals, Digital Medicine (SCI, Expected IF: 5~7) Vol.3, Article No. 54, pp.1-6, 2020

# Example of Physician's Web



## Heart Failure Diagnosis

Patient name:  
홍길동 (11111111)



Home



Diagnosis



Risk Assessment



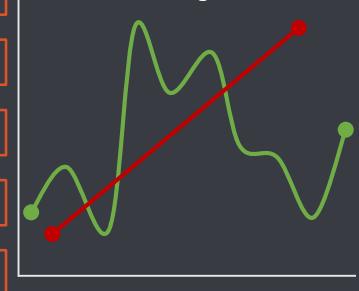
Follow up



### Clinical Status

Congestion		Diuretics Flag	
Dose Increased Flag		Add Diuretics Flag	
ACE inhibitor		Angiotensin receptor blockers (ARB)	
Weight Reduction		NYHA Classification	
Beta-blocker		Left Vent. Ejection Fraction (LVEF)	
ARN Inhibitor		Est. Glomerular Filtration Rate (eGFR)	

Getting Worse



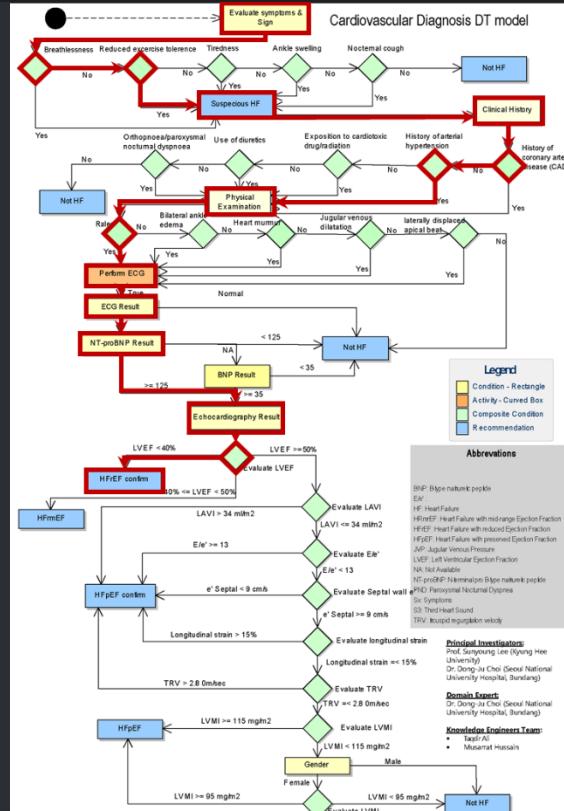
### Clinical Changes



Why: Reason for Diagnosis



### Evidence

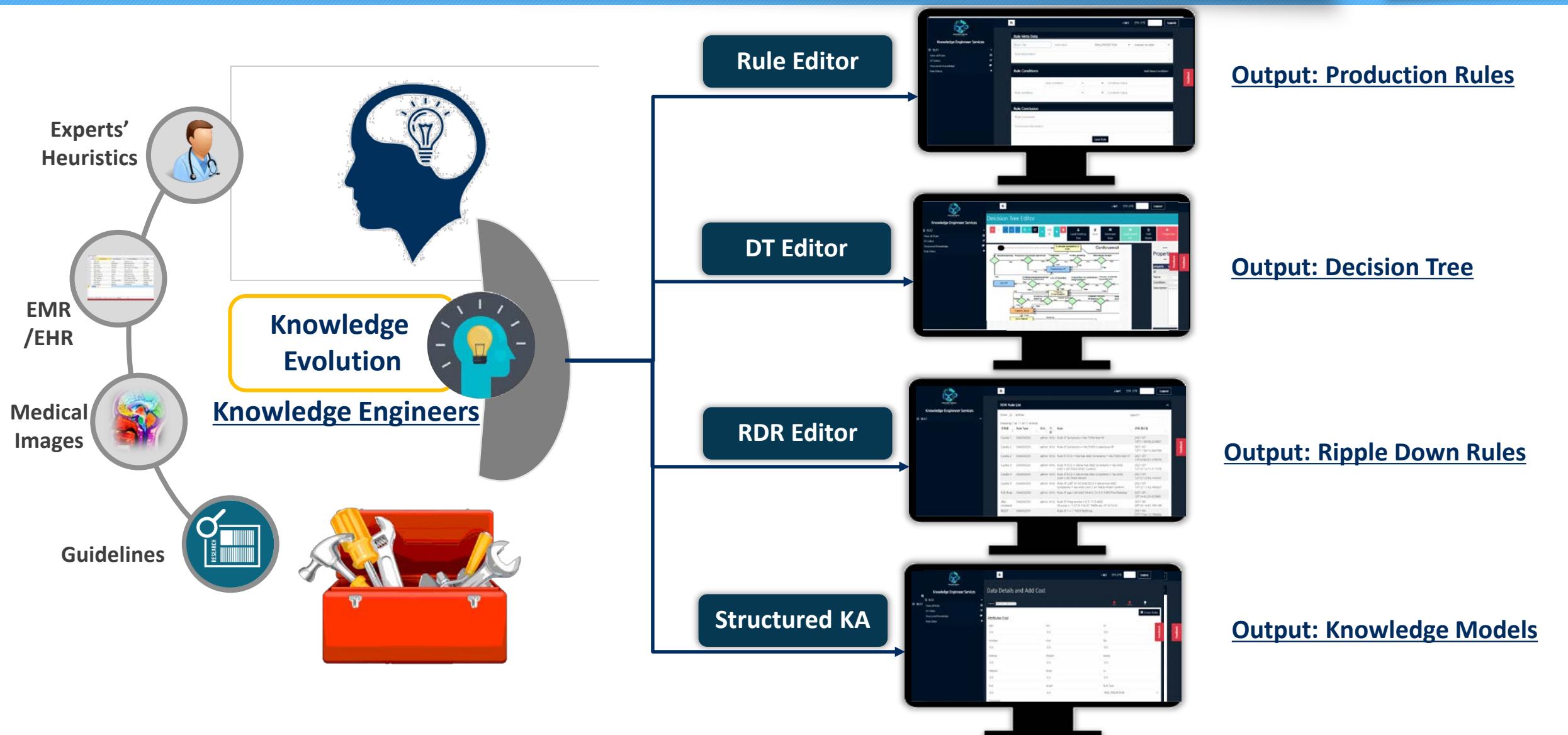


Why: Reason for the Diagnosis

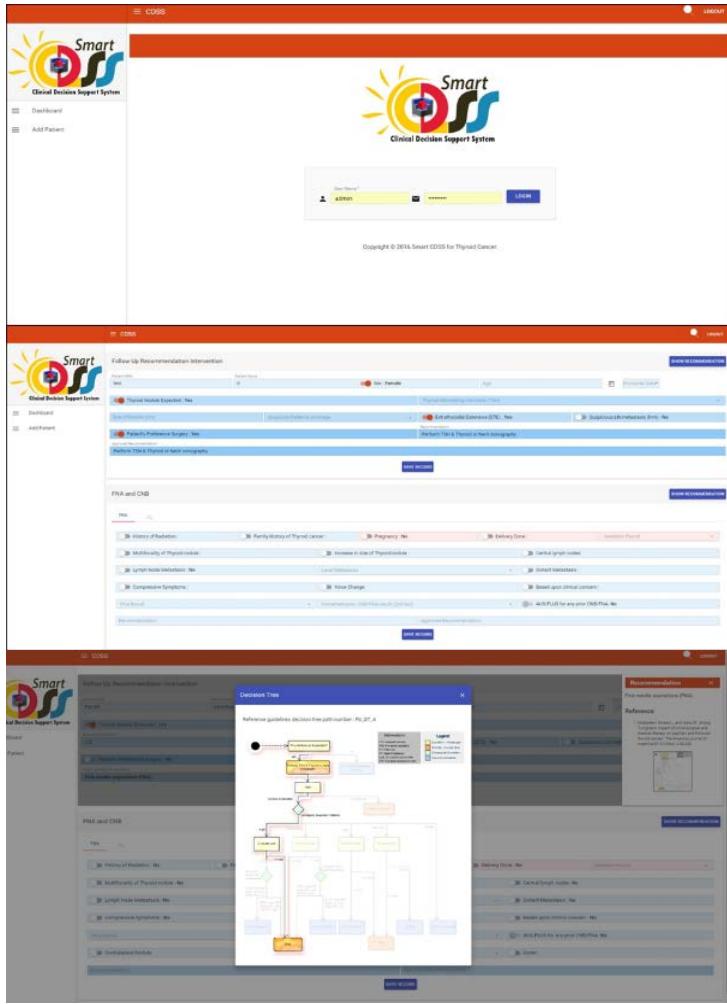
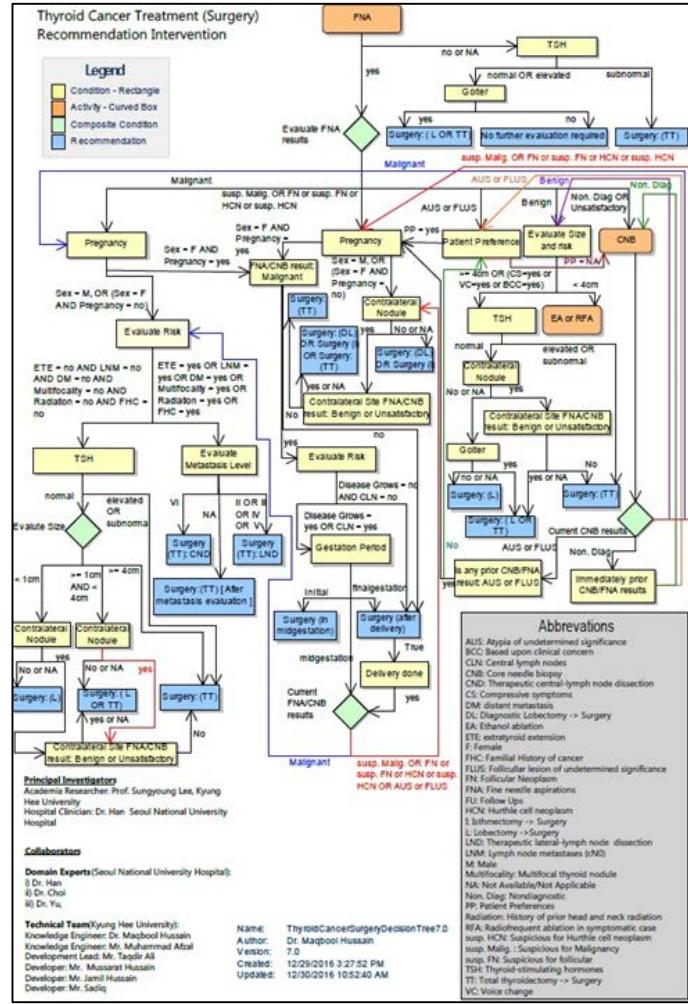
# Engineering Support Tool: I-KAT



32



# Thyroid silo



Manuscript ID amiajnl-2018-006960 entitled "**Use of mind maps and iterative decision trees to develop a guideline-based clinical decision support system (CDSS) for routine surgical practice: Case study in thyroid nodules**" which you submitted to the Journal of the American Medical Informatics Association, has been **Accepted**.

HyungWon Yu, JY Choi, Ho Sung Han, Seoul Natl Univ, Seongnam, Korea, Republic of Korea; Maqbool Husain, Sungyoung Lee, Kyung Hee Univ, Suweon, Republic of Korea

## Next Silo: Adrenal Tumor (Treatment)

- 1차 임상평가 실시
    - 총 292명의 환자 데이터 사용, 총 3,040개 를 생성
    - 81.51%의 평균 정확도를 도출하였으며, 각각의 예외 케이스를 처리한 경우 97.95%로 정확도가 향상되었음.

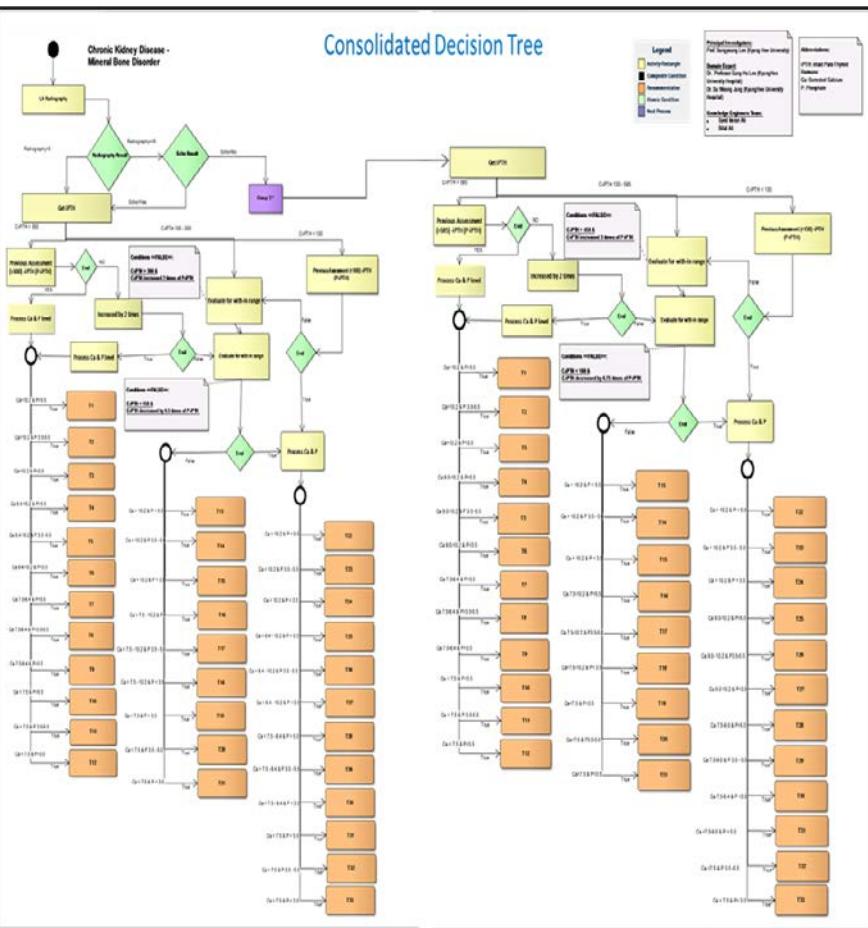
- 2차 임상평가 실시
    - 총 483명의 환자 데이터 사용, 총 3,700개 를 생성
    - 78.9%의 일치율을 나타냈으며, 추천의 정확도를 높이기 위해 나머지 21.1%의 불일치 케이스에 대한 연구 진행중임.

- **지식병합**(의사 지식 + 환자데이터 지식) 및 3차 임상평가  
진행
    - 환자데이터 자체를 기계학습기법으로 분석하여 병합
    - **1,000명** 내외의 환자 데이터 수집 및 모델링

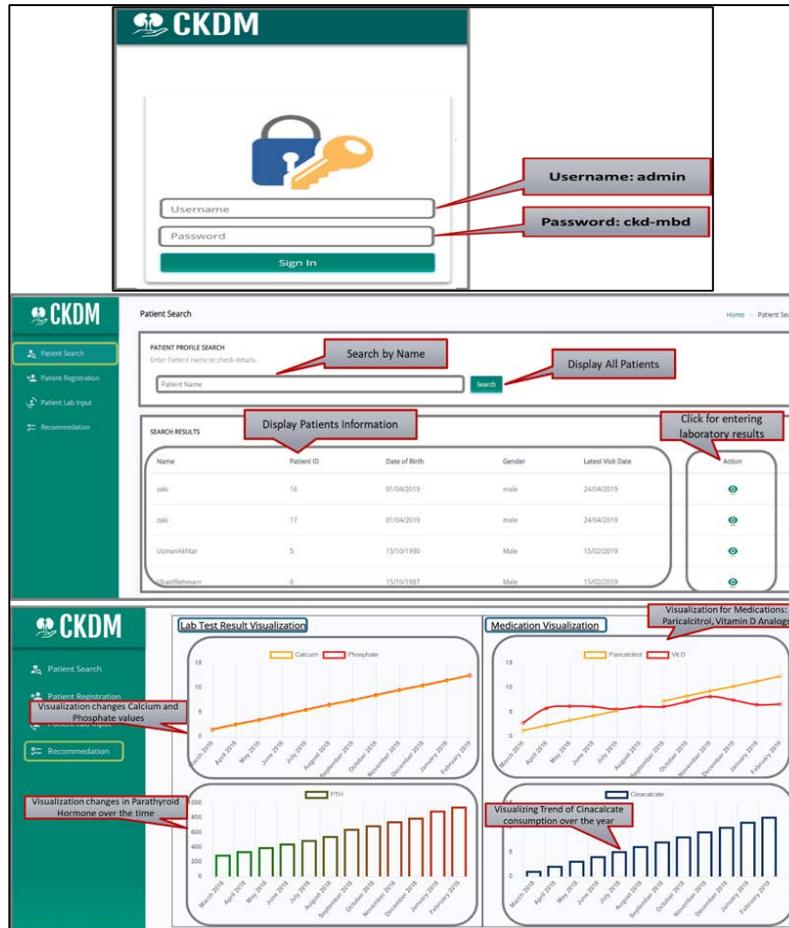
# Kidney silo, CKD-Bone Mineral Disorder Treatment



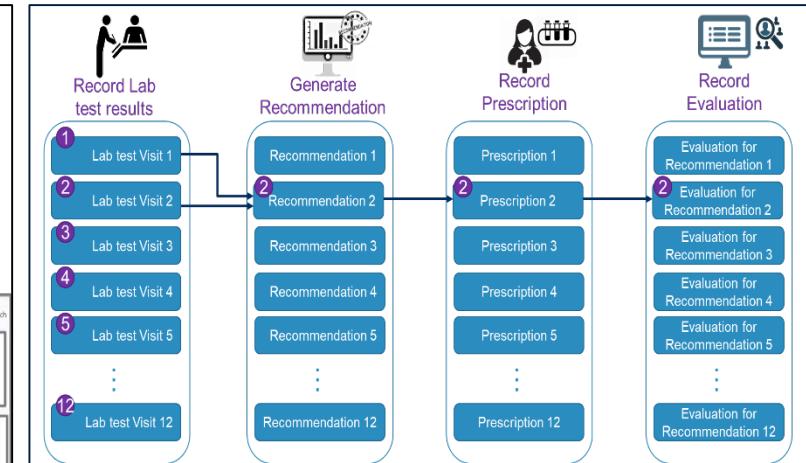
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CKD-MBD 치료 지식베이스



시스템 인터페이스



- **임상평가 실시 (환자 당 13개월 기간의 데이터 적용)**
  - 총 **63명**의 환자 데이터, 총 **851가** 추천 개수로 구성
  - 평가 일치율 **85%** 달성

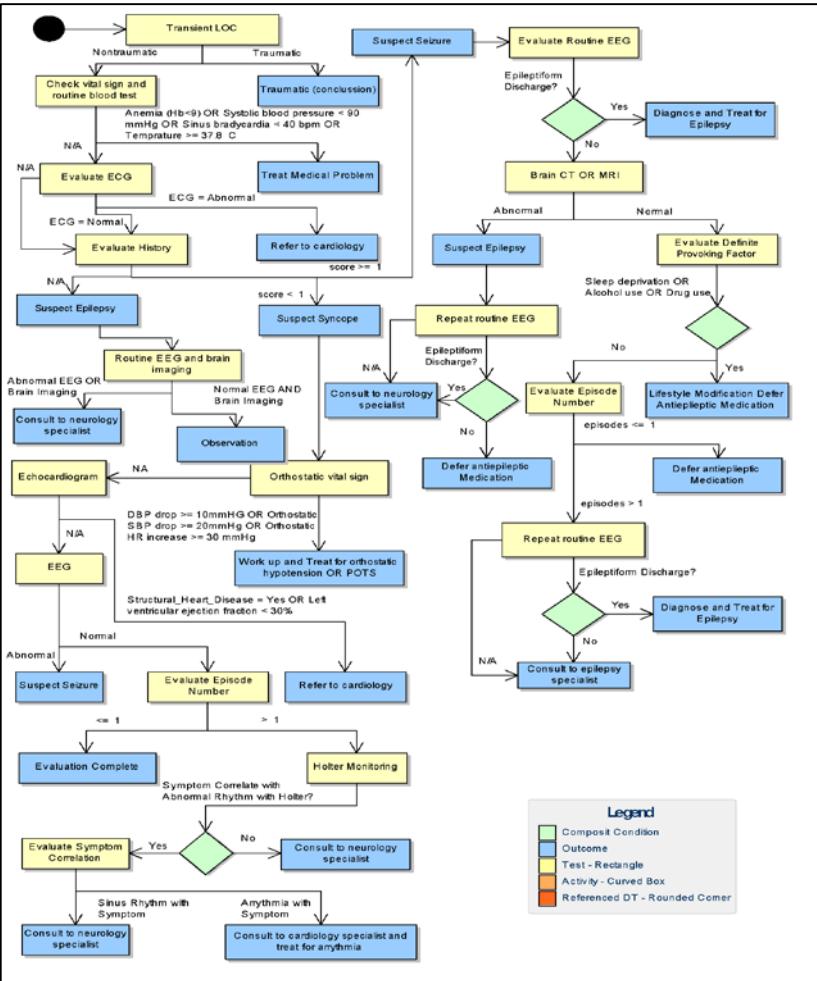
- **임상평가 결과의 학술저널 발표 진행 중**

임상평가 실시 / 진행중인 사항

# Epilepsy silo



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뇌전증 진단 지식베이스

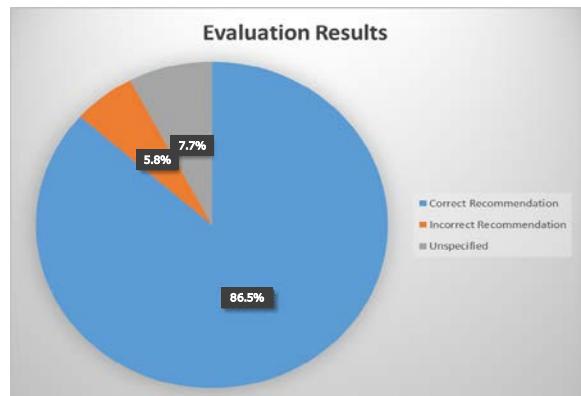
The interface shows the 'Epilepsy Diagnostic System' login screen with fields for 'User Name' and 'Password', and a 'LOGIN' button. Below it is a copyright notice: 'Copyright © 2018.Smart CDSS for Epilepsy Disease.' The main area displays a patient list table:

Patient MRNo	Name	Date of Birth	Gender	Encounter Date	Action
03096774	Buyeon Choi	1972-09-28	Female		
04588795	Young Il Cho	1942-05-21	Male		
06117715	Ju Young Park	1980-09-27	Male		
06125183	In Hyeon Choi	1984-01-10	Male		
00081415	Hae Jin Choi	1962-04-04	Male		

Below the table is a 'Patient Vital Sign' section showing a 'CDSS Intervention' table with a 'Recommendation: Lifestyle Modification Defer Antiepileptic Medication' row. A legend defines symbols: green square for Composite Condition, blue square for Outcome, yellow rectangle for Test - Rectangle, orange rounded rectangle for Referenced DT - Rounded Corner, and red rounded rectangle for Decision Tree.

시스템 인터페이스

- 1차 임상평가 실시
  - 총 52명의 환자 데이터, 총 851개 추천 개수로 구성
  - 진단 정확도 86.5% 달성

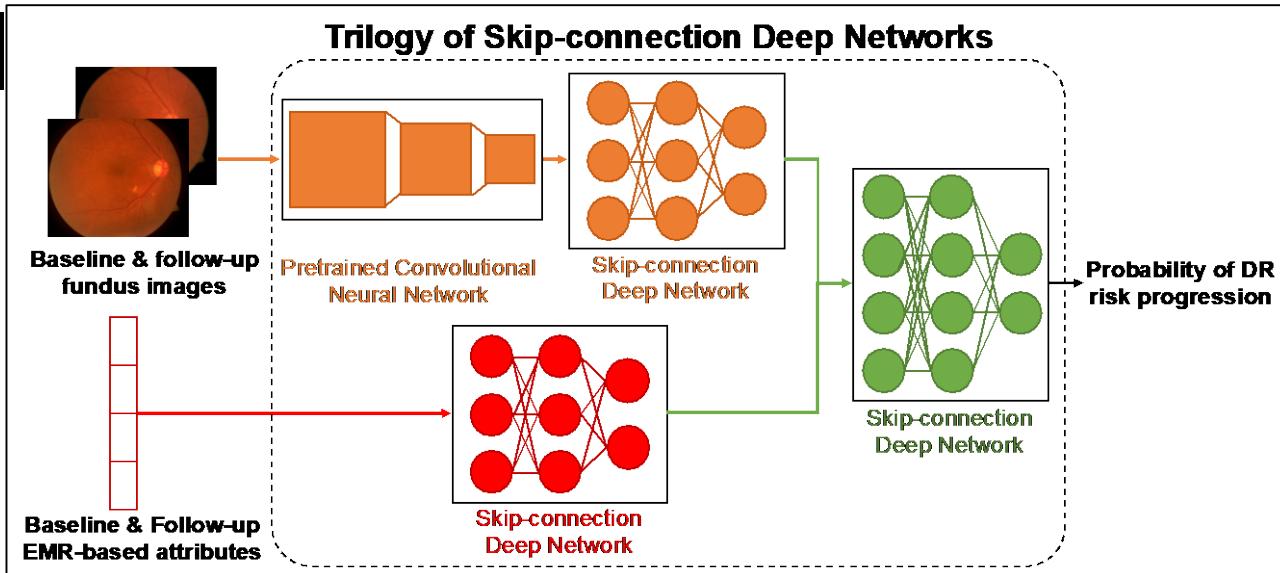


- 2차 임상평가 진행 중
  - 1차 평가 결과의 분석을 통한 Decision Tree 보강
  - 다양한 평가용 환자 데이터 사용

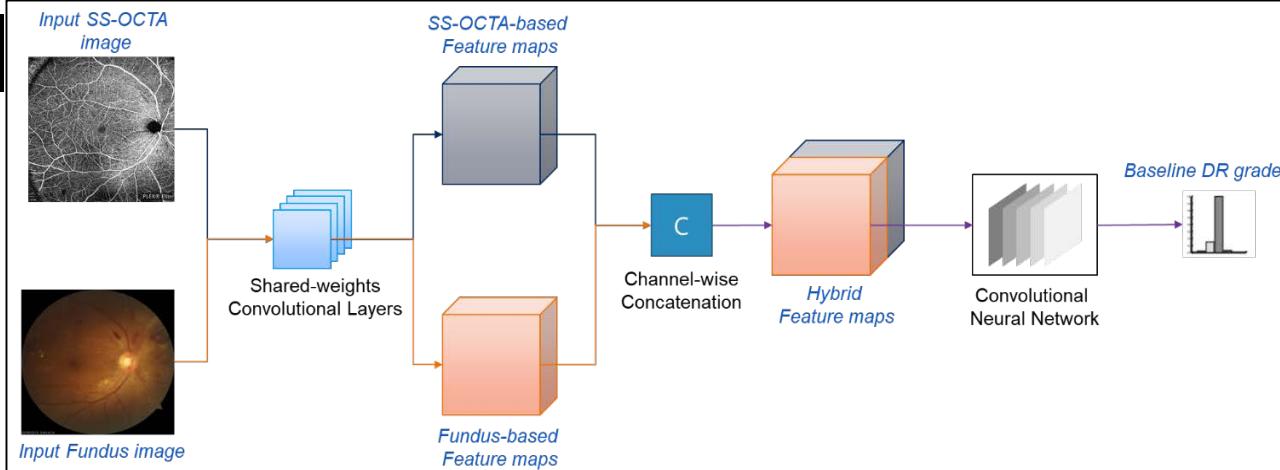
- 1차/2차 임상평가 결과의 학술저널 발표 진행 중

임상평가 실시 / 진행중인 사항

당뇨망막증  
silo 구현



당뇨망막증  
silo 확장



International Journal of Medical Informatics 132 (2019) 103926

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journal homepage: [www.elsevier.com/locate/ijmedinf](http://www.elsevier.com/locate/ijmedinf)



Bimodal learning via trilogy of skip-connection deep networks for diabetic retinopathy risk progression identification

Cam-Hao Hua<sup>a</sup>, Thien Huynh-The<sup>b</sup>, Kiyoung Kim<sup>c</sup>, Seung-Young Yu<sup>c</sup>, Thuong Le-Tien<sup>d</sup>, Gwang Hoon Park<sup>a</sup>, Jaehun Bang<sup>a</sup>, Wajahat Ali Khan<sup>a</sup>, Sung-Ho Bae<sup>a,\*</sup>, Sungyoung Lee<sup>a,\*</sup>

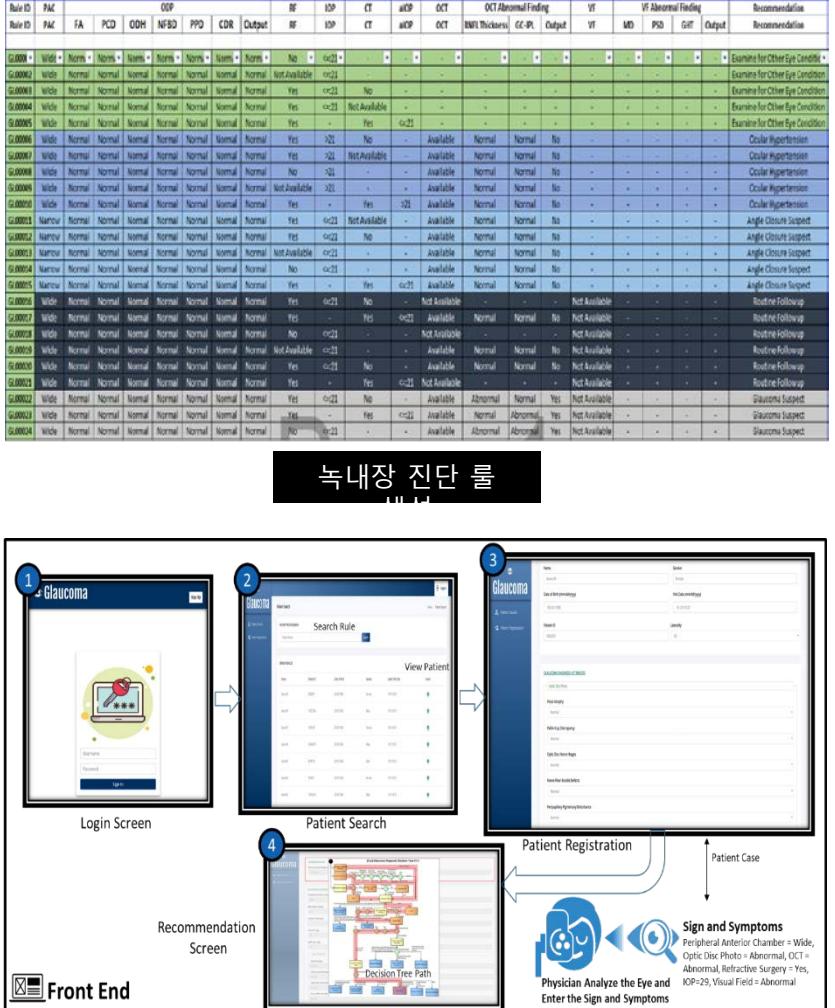
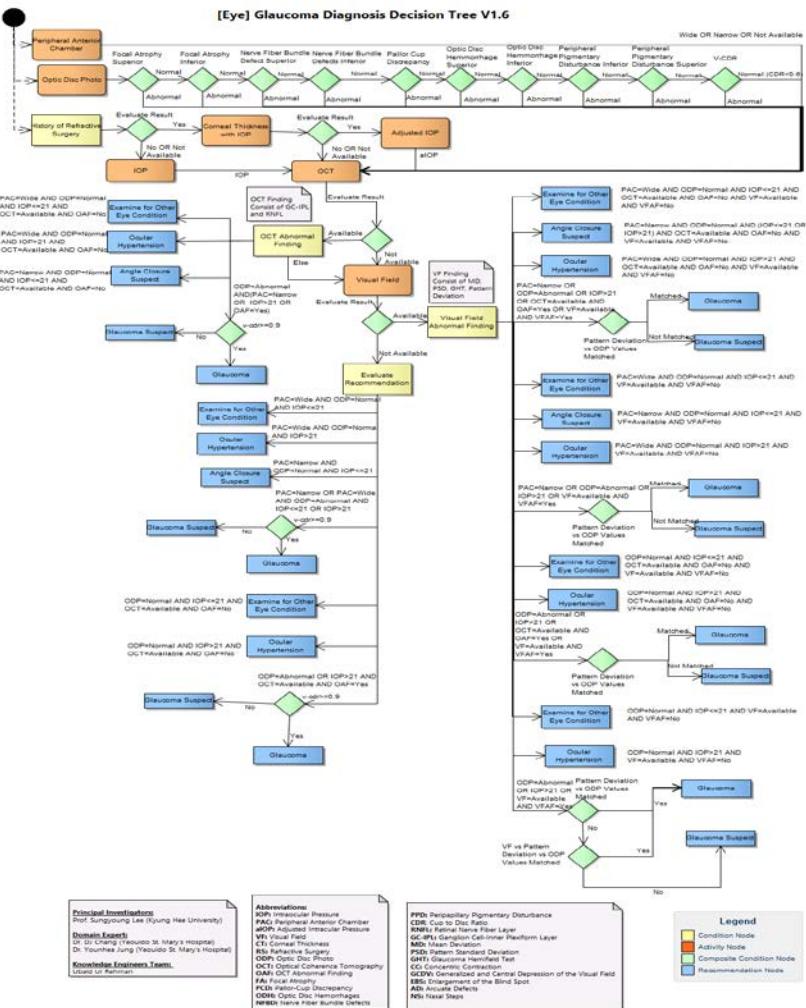
- 1차 임상평가 실시 (DR 진행정도의 파악: Tri-SDN)
  - 총 96명의 환자 데이터
  - 경험이 풍부한 경희의료원 안과의사 5명의 경험치와 비교
  - 정확도, 민감도, 정밀도, 특수성, ROC커브 등에서 월등한 성능을 나타냄.
  - 1차 임상평가 결과를 IJMI (SCI) 저널에 발표

Strategy	Acc (%)	Sen (%)	Pre (%)	Spe (%)	AUROC (%)
EMR-DN	$83.3 \pm 1.1$	$96.5 \pm 0.7$	$79.7 \pm 1.3$	$64.1 \pm 3.5$	$83.6 \pm 2.0$
Tri-DN	$86.5 \pm 0.9$	$96.5 \pm 1.5$	$83.3 \pm 1.2$	$71.8 \pm 3.0$	$86.4 \pm 1.5$
Tri-SDN	$90.6 \pm 0.7$	$96.5 \pm 1.2$	$88.7 \pm 1.0$	$82.1 \pm 3.0$	$88.8 \pm 1.4$

- 2차 임상평가 실시 (SS-OCTA 추가: DR 기준등급 분류 성능 개선)
  - 약 9.8% QWK(Quadratic Weighted Kappa)값 향상 ( $80.4 \leftrightarrow 90.2\%$ )
  - 2차 임상평가 결과를 IEEE J-BHI (JCR 상위 10%) 저널에 발표

- 3개 이상의 멀티모달 구조로 확장 및 임상평가 규모 확대실시 진행

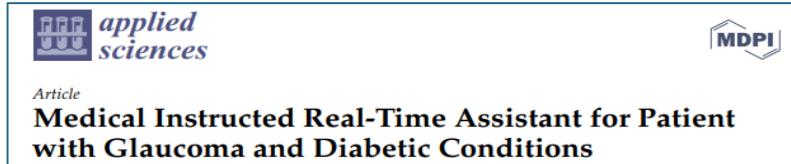
# Glaucoma Diagnosis Silo



- 환자 안내용 챗봇 제작
  - 근처의 전문의를 안내해주는 환자 안내용 챗봇
  - 현재까지 녹내장과 당뇨 유증상 환자만 대상

- 환자 안내용 챗봇 시험
  - 3가지 질병(녹내장, 당뇨, 기타)별 환자 33명의 말뭉치
  - 녹내장 89.8%, 당뇨 84.8%, 기타 93.9% 정확도

환자 안내용 챗봇 제작



- 임상평가 실시
  - 총 300명의 환자 데이터 사용, 총 20,433개 를 생성
  - 전체적으로 82%의 진단 정확도를 달성 (녹내장 78.5%, 녹내장 의심 81.9%, 일상적 후속조치 95.4% 등)

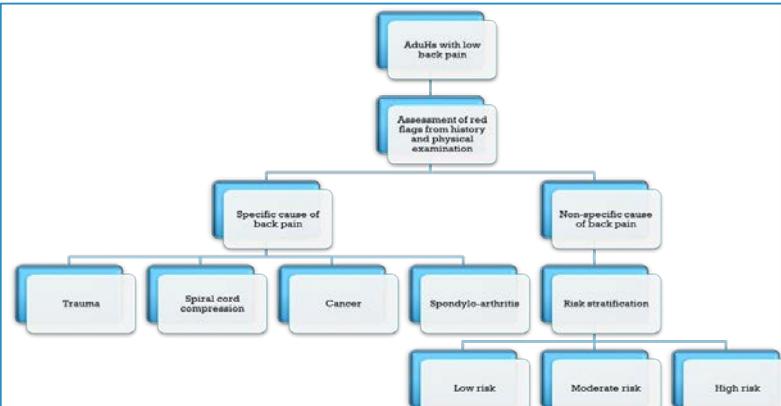
- 지식베이스 개선
  - 진단 정확도 향상을 위해 기여인자 체계 변경 (기여인자 25개 ⇒ 68개, 생성 룰 833,976개)

- 지식병합(의사 지식 + 환자데이터 지식) 진행 중
  - 환자데이터 자체를 기계학습기법으로 분석하여 병합

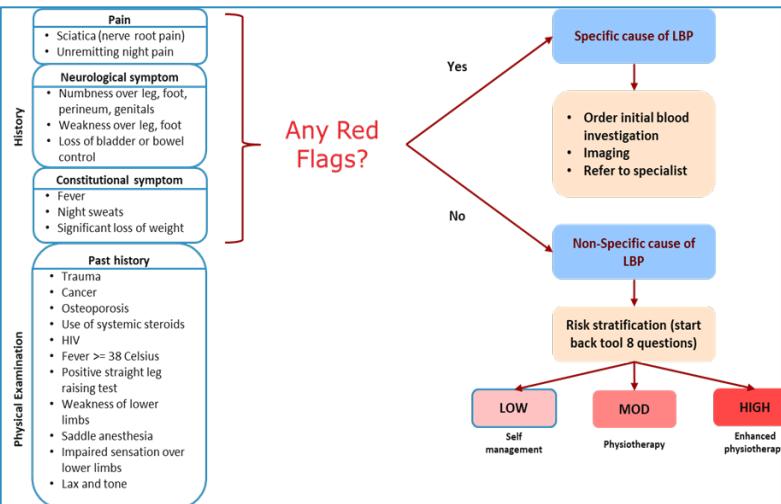
# Back Pain Silo



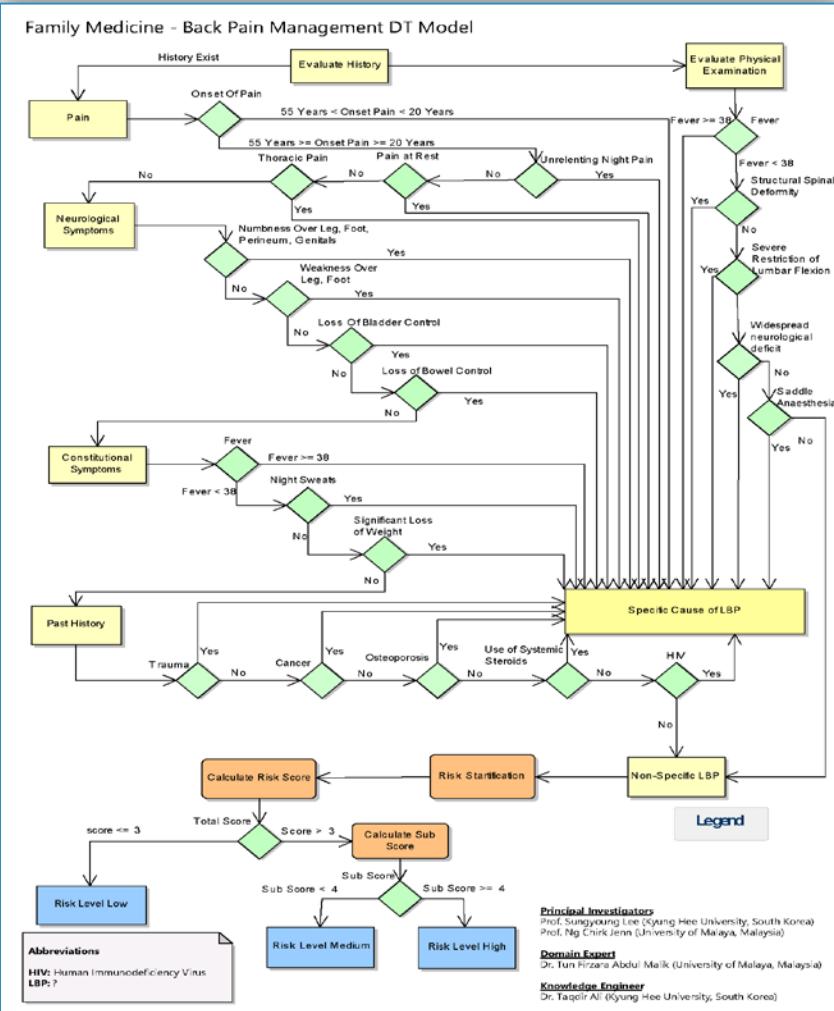
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## 요통 발생 원인 및 위험도 분류



요통 진단 마인드맵



## 요통 진단 지식베이스

**User Id** →   
**Password** →   
← **Login Button**

MRN	Name	Gender	Date of Birth	Total Encounters	Most Recent Encounter Date	Actions
1	Patient 1	male	1990-02-02	1	2020-01-10T12:18:47.553	<a href="#">Edit</a> <a href="#">View Encounters</a>
2	Patient 2	male	1977-02-03	1	2020-01-19T13:53:48.140	<a href="#">Edit</a> <a href="#">View Encounters</a>
3	Patient 3	male	1988-02-03	1	2020-01-15T14:12:43.433	<a href="#">Edit</a> <a href="#">View Encounters</a>
4	Patient 4	male	1999-02-02	1	2020-01-17T22:00:42.042	<a href="#">Edit</a> <a href="#">View Encounters</a>

시스템 인터페이스

- **모의 임상평가 실시**
    - 총 **107명**의 말라야대학병원 환자 데이터 사용
    - 특정질환으로 인한 요통 발병(38명)은 모두 의사의 추천과 일치
    - 불특정 원인에 의한 요통 발병의 경우 환자 데이터 불완전성으로 오류 발생 (의료진과 협의중)

- 임상평가 확대실시 진행 중
  - 말라야대학병원 EMR과 연동 추진

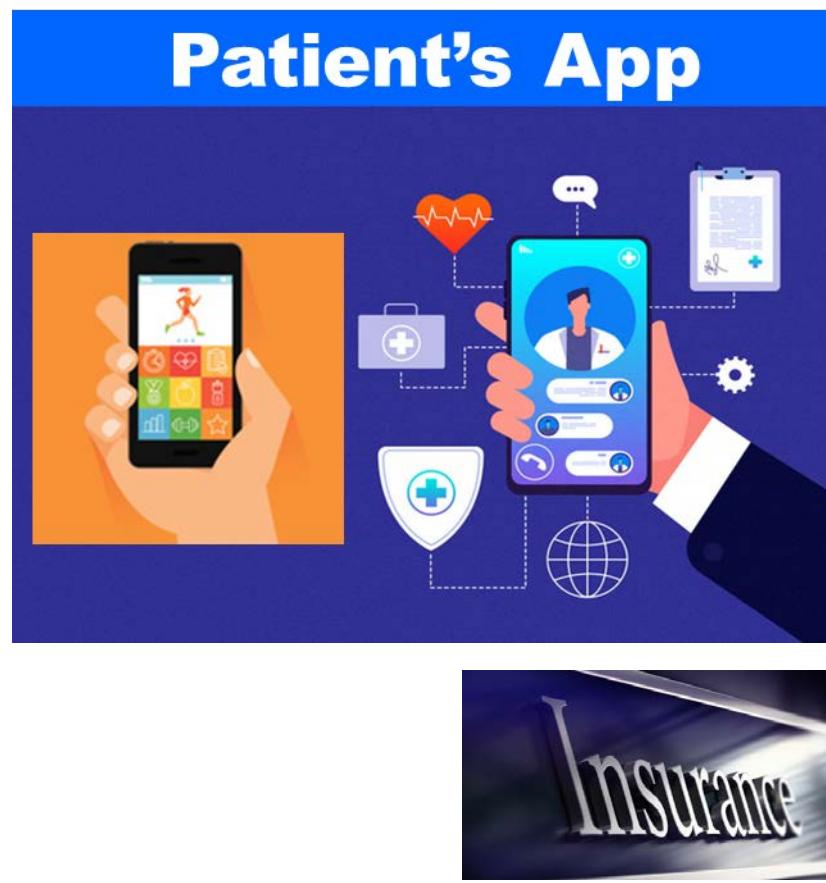
## 임상평가 실시 / 진행중인 사항

## Silo

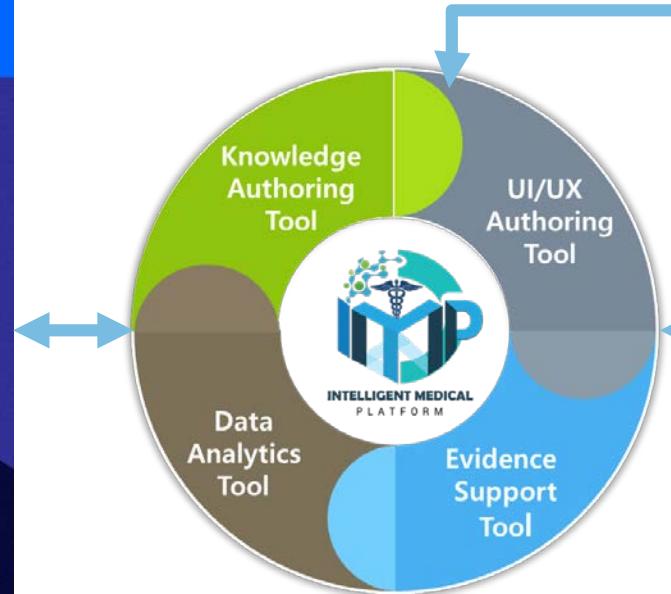
1. [Glaucoma Silo] Ubaid Ur Rehman, et al. "Medical Instructed Real-time Assistant for Patient with Glaucoma and Diabetic Conditions", Applied Sciences (SCIE, IF: 2.217), doi:10.3390/app10072216, 2020
2. [HF Silo] Dong-Ju Choi, et al. "Artificial intelligence for the diagnosis of heart failure", Nature Partner Journals, Digital Medicine (SCI, Expected IF: 5~7) Vol.3, Article No. 54, pp.1-6, 2020
3. [DR Silo] Cam-Hao Hua, "Bimodal Learning via Trilogy of Skip-connection Deep Networks for Diabetic Retinopathy Risk Progression Identification", International Journal of Medical Informatics (SCI, IF:2.731), Vol.132 , 2019
4. [Thyroid Silo] HyungWon Yu, "Use of mind maps and iterative decision trees to develop a guideline-based clinical decision support system for routine surgical practice: Case study in thyroid nodules", Journal of the American Medical Informatics Association (SCI, IF:4.292), Volume 26, Issue 6, EISSN: 1527-974X, pp.524–536, 2019
5. [Kidney Silo] Syed Imran Ali, "Ensemble feature ranking for cost-based non-overlapping groups: A case study of chronic kidney disease diagnosis in developing countries", IEEE Access (SCIE, IF:3.745), Accepted, 2020

## Platform

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Admin dashboard



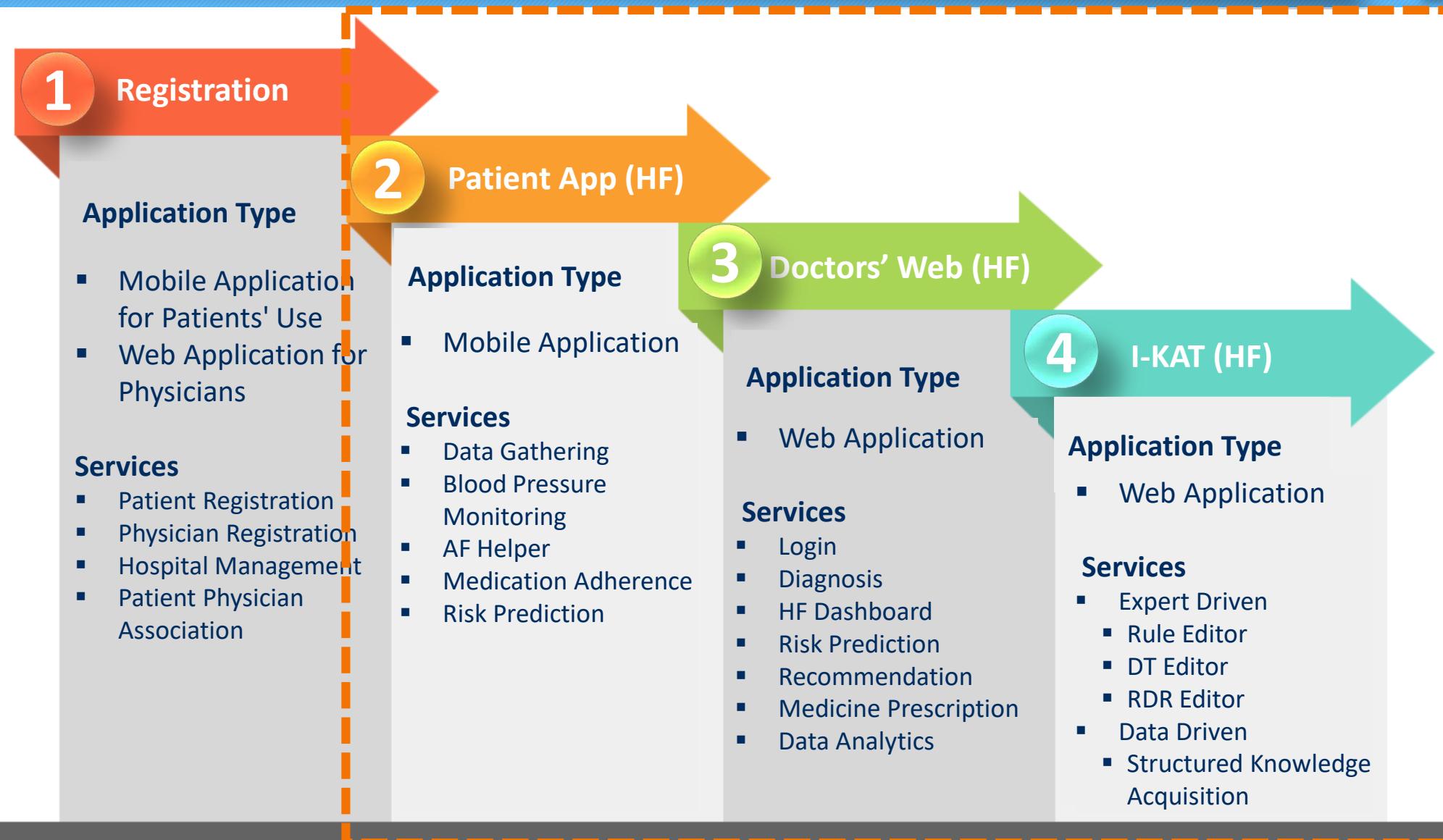
Platform/Tools



# Example of Business Solutions



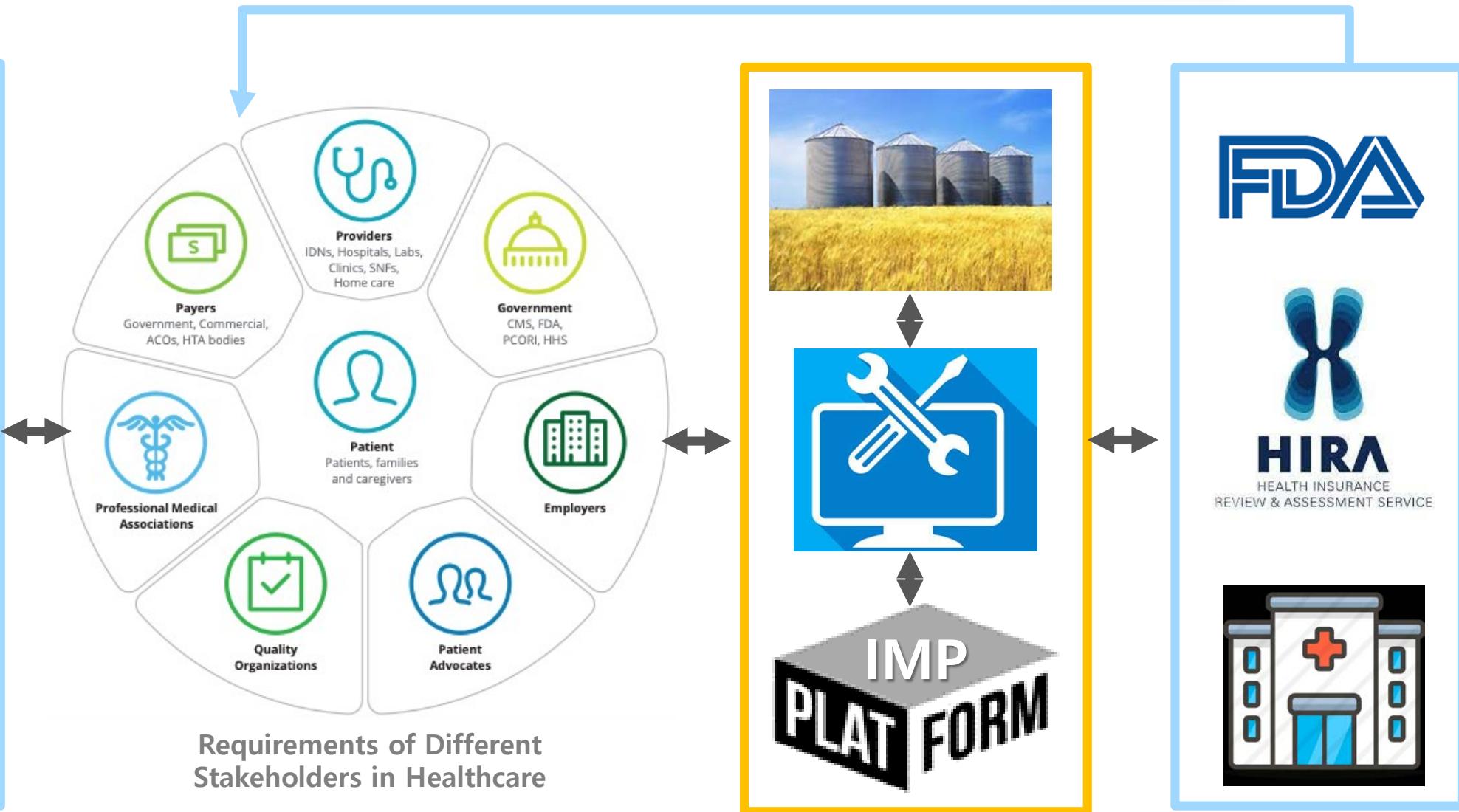
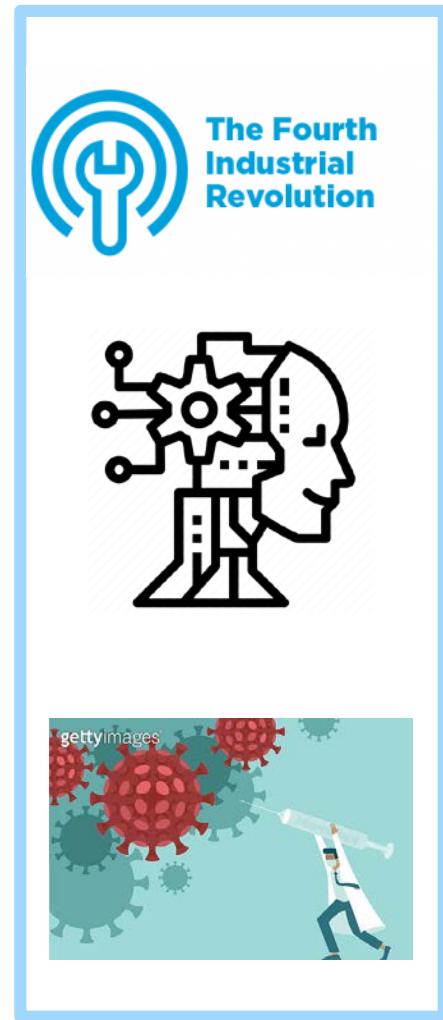
41



# Journey of AI Healthcare Platform



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# Many Thanks