HEALS: Health Examination Automatic Logic System

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Introduction

Health Examinations

- Health examinations play important roles in preventive medicine.
- The clinical condition of an individual continuously changes and needs a series of observations and follow-up.
- In the past, in order to meet such requirement, clinical workers have to fetch health examination data from scattered sources, such as medical charts or general-purpose hospital information system.

Health Examinations

- The lack of a health examination information system meant that the availability, efficiency, and quality of further health care management would degrade.

Asymmetry between Rural and Urban Medical Settings

- Scale
- Equipment
- Quality
- Information technology

HEALS: History

- A health care system developed in Taipei City Hospital since 1996 (original Taipei Municipal Jen Ai Hospital)
- Dedicated for health examinations

HEALS: Overview

- Fully web-based application
- Services provided via ubiquitous Internet accessing
- Enormous applications of the database
- Integrate healthcare domain knowledge to provide sophisticated user-defined functions and interfaces
- Built-in decision-support system for automatic report generation including medical data interpretation, automatic summary, and suggestion

HEALS: Overview

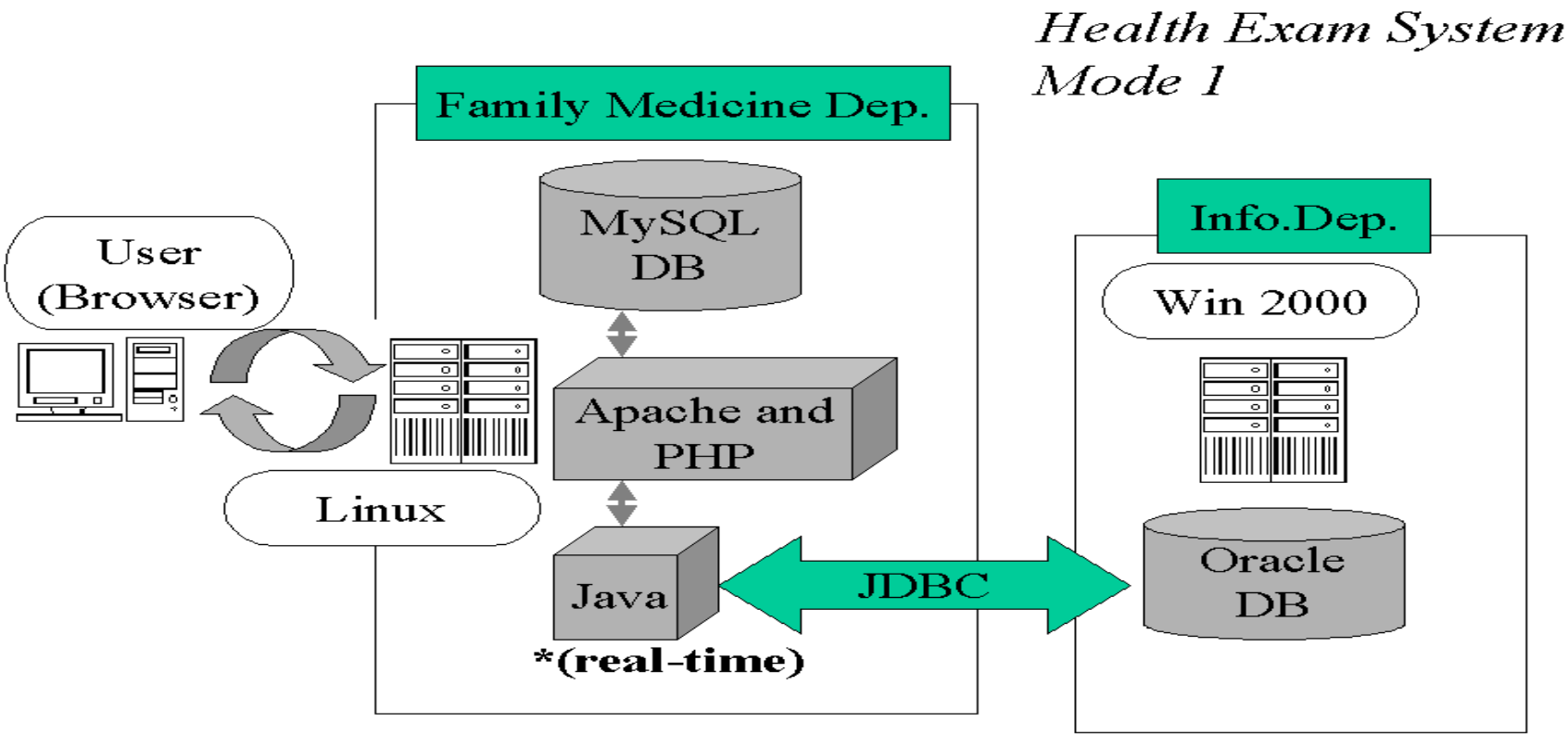
- Provides a user-friendly, intelligent, fully-functional application experience to clinical workers in a distributed way
- Rural clinics can seamlessly share the services provided by HEALS via web-browsing
- Customers can also easily derive integrated healthcare information from HEALS under certain security authentication

HEALS: Overview

- Web-based:
  - PHP
  - Java
- Database:
  - SQL compliant

PHP: Personal Home Page
SQL: Structured Query Language

HEALS: Integrated into HIS

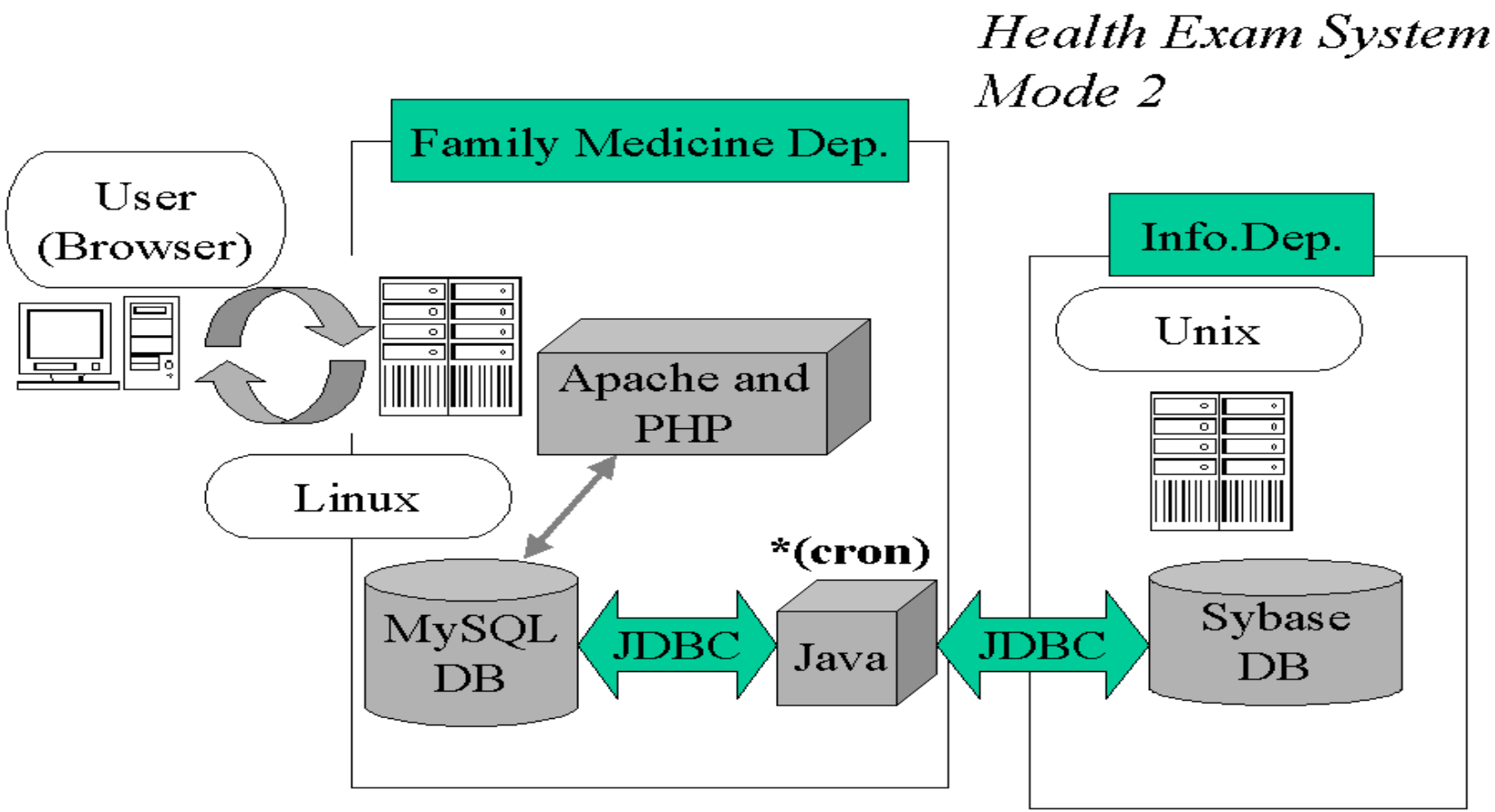


HIS: Health Information System

DB: Data Base

JDBC: Java Data Base Connectivity

HEALS: Integrated into HIS

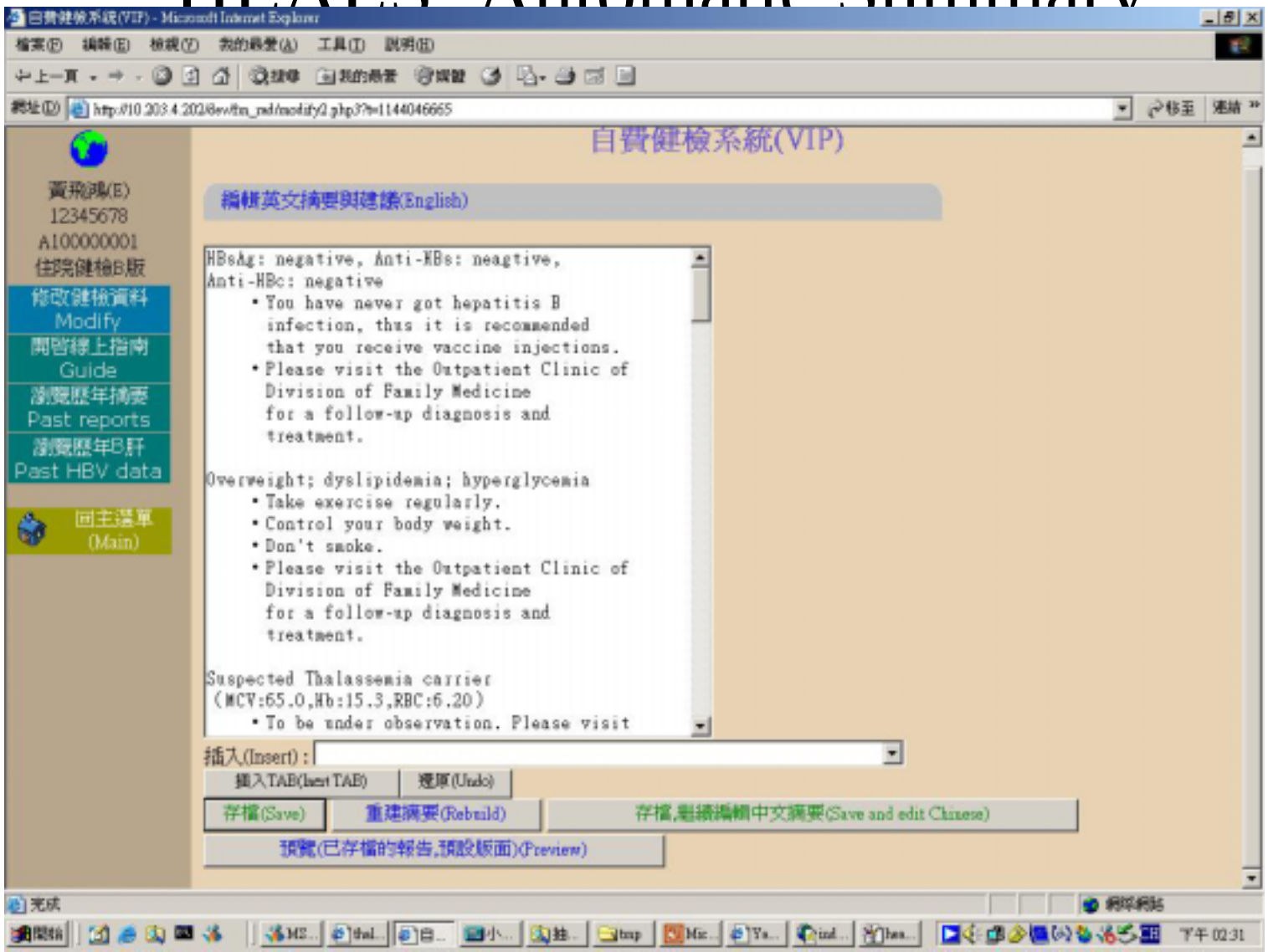


Screen Shots

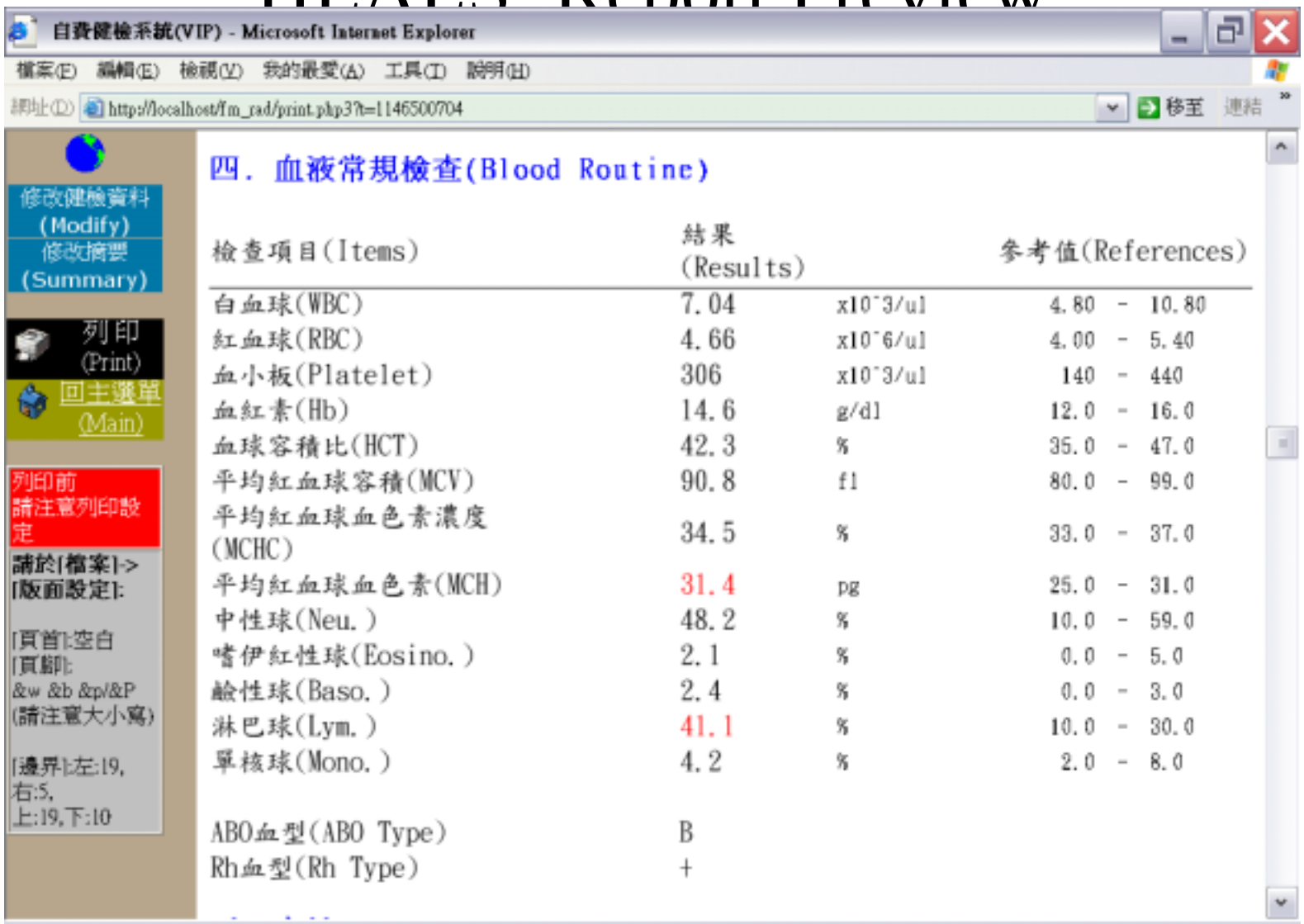
HEALS: Portal Page

HEALS：Results Input

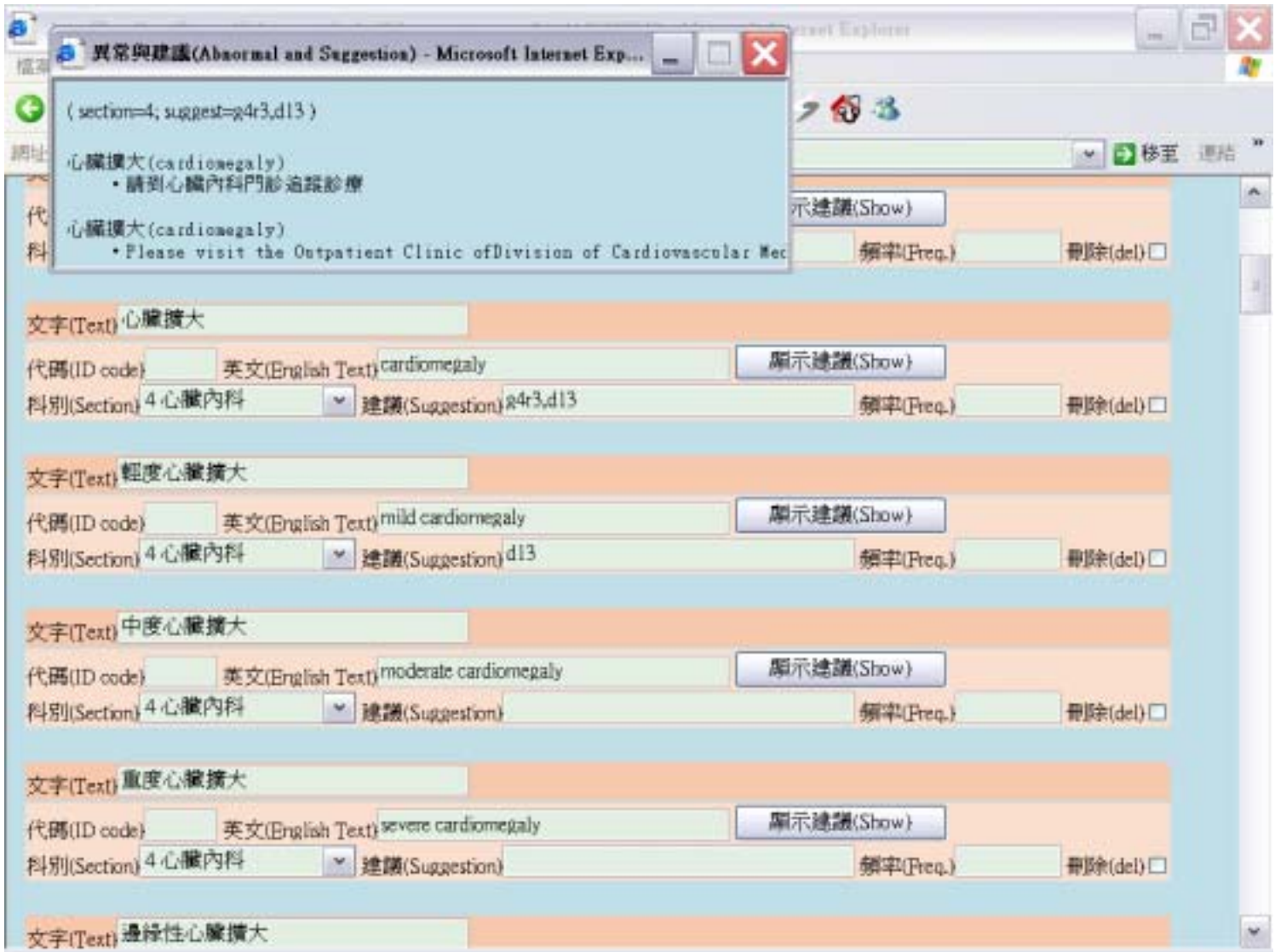
HEALS: Automatic Summary



HEALS: Report Preview

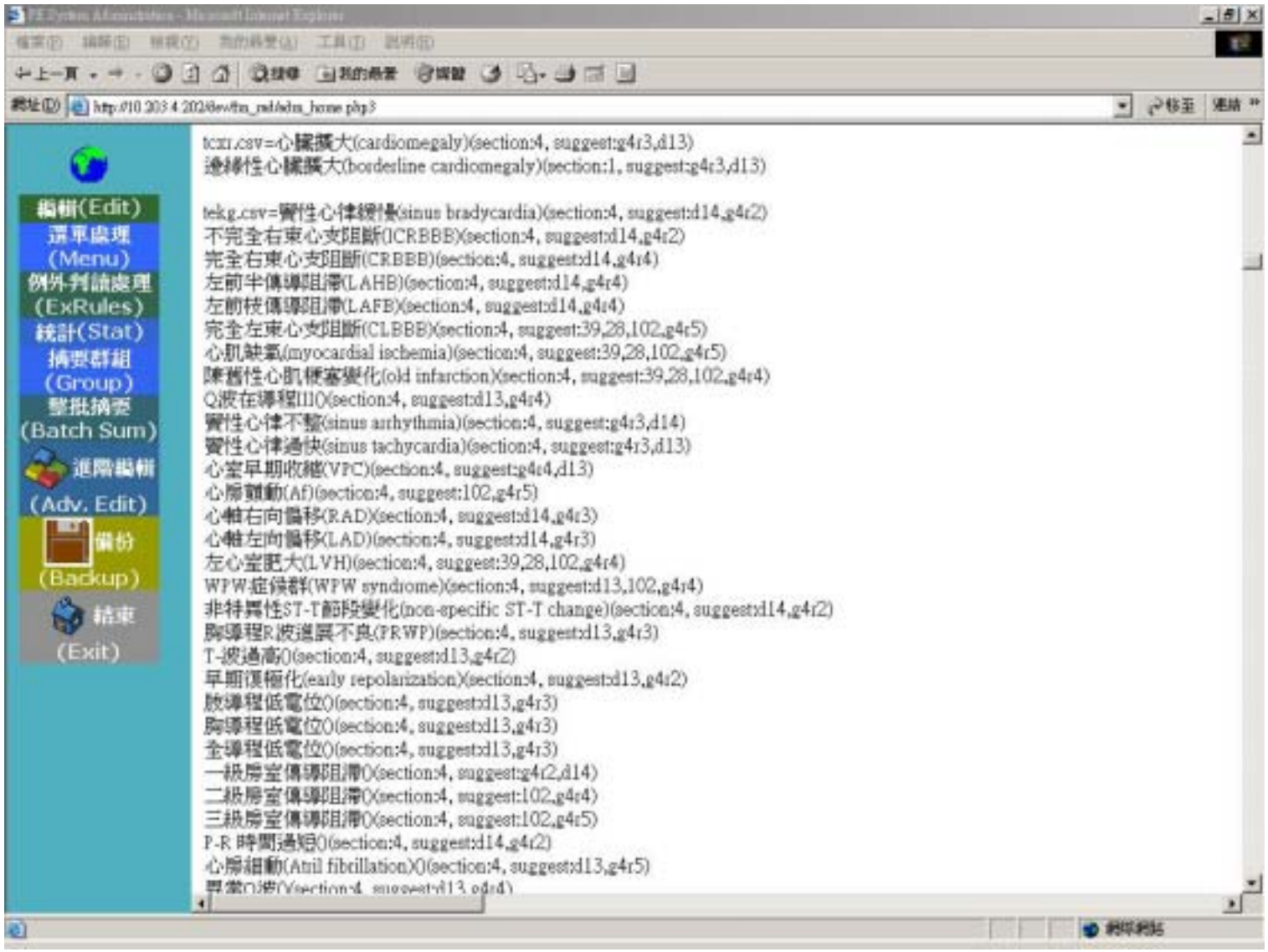


HEALS: Maintenance of Phrases and Inference Information



HEALS: Maintenance of Inference Information

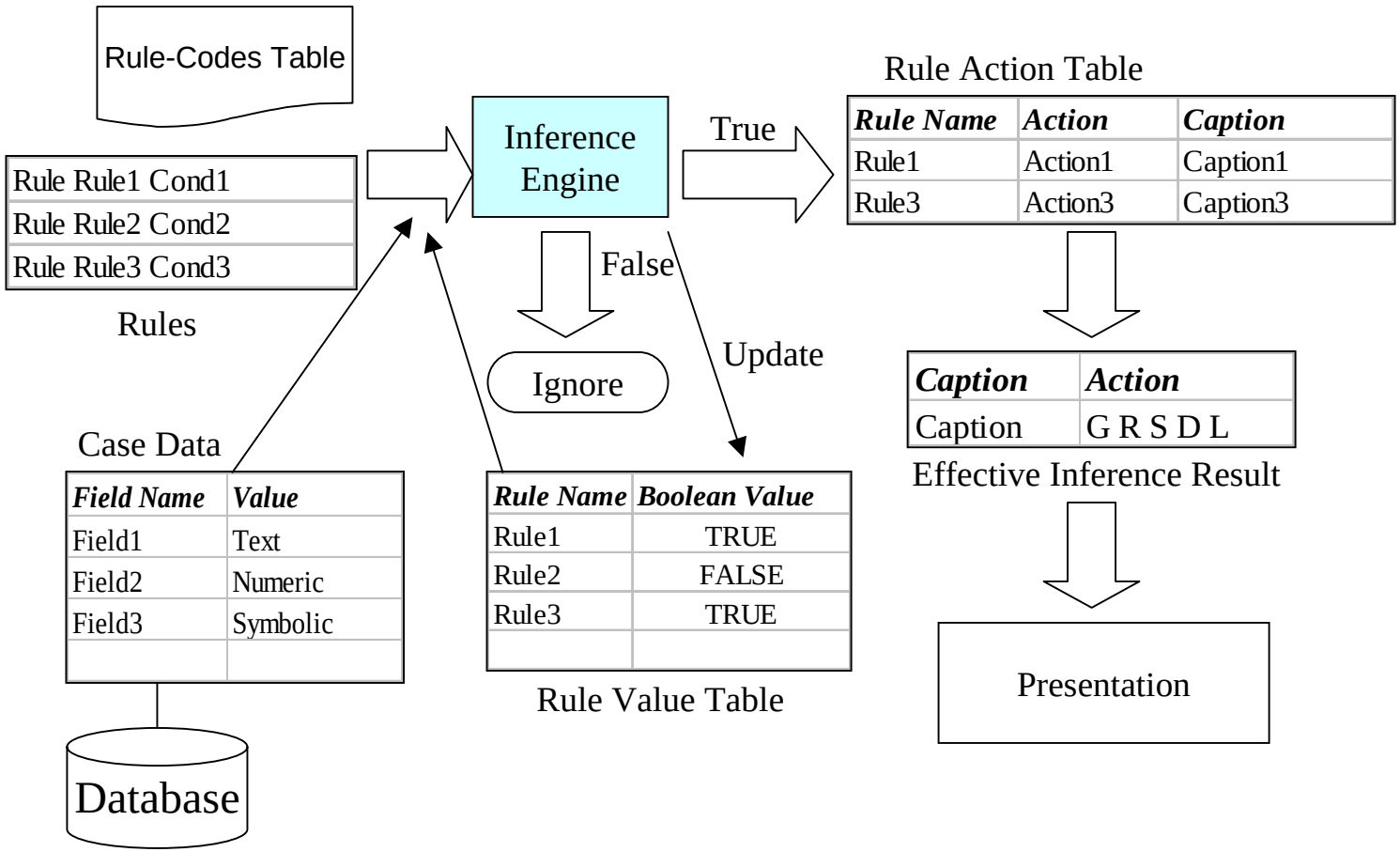
HEALS: Maintenance of Inference Information



Implementation of CDSS in HEALS

CDSS: Clinical Decision Support System

Implementation of CDSS in HEALS: Inference Engine



Implementation of CDSS in HEALS:
Rules Syntaxes

limitdef <name> <condition>

rangedef <name> <condition>

clausedef <name> <condition>

ruledef <name> <condition>

Implementation of CDSS in HEALS: Rule Example

Syntax:

limitdef <name> <condition>

Example:

limitdef HBSAG_pos HBSAG == "+"

Implementation of CDSS in HEALS:
Rule Example

Syntax:

rangedef <name> <condition>

Example:

rangedef HB_mildLow HB [10 12)

Description:

HB>=10 and HB<12 (HB: hemoglobin)

Implementation of CDSS in HEALS:

Rule Example

Syntax:

clausedef <name> <condition>

Example:

clausedef RFT_H CR_H || BUN_H

Description:

CR_H: pre-defined rule with the condition of high Creatinine

BUN_H : pre-defined rule with the condition of high BUN

Implementation of CDSS in HEALS:

Rule Example

Syntax:

ruledef <name> <condition>

Example:

ruledef HBV_nnn HBSAG_neg && HBSAB_neg && HBCAB_neg && !AGE_50

Description:

HBSAG_neg: pre-defined rule with the condition of negative HBsAg.

Implementation of CDSS in HEALS: Inference Results

Triggered action:

Section code; Suggestion Codes

Example:

1;D20,G24R2,T82

Description:

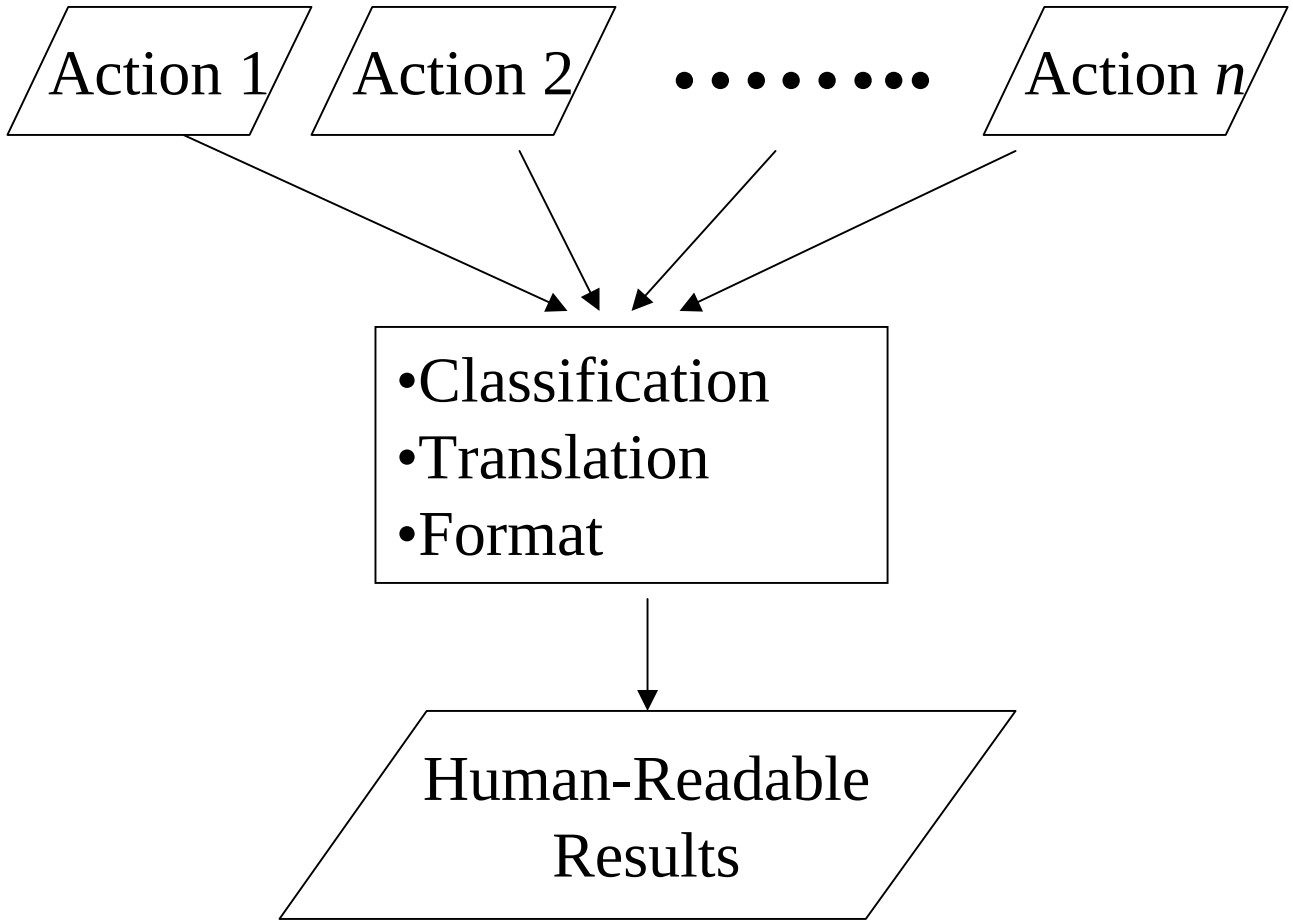
1: Division of Family Medicine

D20: To be under observation. Please visit the Outpatient Clinic of $$ for a follow-up diagnosis and treatment, in the event of doubts or discomfort.

G24R2: group 24, rank 2

T82: r/o Thalassemia

Implementation of CDSS in HEALS: Effective Inference Results



Summary and Conclusion

Advantages of HEALS

- Provide services beyond the territory boundary between rural and urban medical settings
- Improve the quality of health examination information flow.
- Improve the efficiency of health examination information flow.
- Reduce the mundane daily work of clinical workers
- Provide education for junior doctors
- Eliminate common misses in health reports

Common Misses in Health Reports

- Fail to correctly detect problems from multiple examination results
- Fail to give proper suggestions for further medical management or life style modification
- Fail to write a well-edited report
- Fail to meet the deadline for sending reports

Common Misses in Health Reports:

Fail to correctly detect problems from multiple examination results

- Anemia:
  - RBC (red blood cell count)
  - Hb (hemoglobin)
  - MCV (mean corpuscle volume)

Common Misses in Health Reports:

Fail to correctly detect problems from multiple examination results

- Hepatitis B:
  - HBsAg (hepatitis B surface antigen)
  - Anti-HBs (hepatitis B surface antibody)
  - Anti-HBc (hepatitis B core antibody)
  - HBeAg (hepatitis B e antigen)
  - Liver enzymes
  - Abdominal sonography

Common Misses in Health Reports:

Fail to give proper suggestions for further medical management or life style modification

- To give a succinct and complete suggestion at a time is a difficult job.

Common Misses in Health Reports:

Fail to write a well-edited report

- Different quality by different doctors
- Different quality by a doctor at different time

Common Misses in Health Reports:

Fail to meet the deadline for sending reports

- Regular workload of a doctor in the health examination center
  - 20 reports/day
- Per report's conclusion time requirement:
  - With CDSS: in seconds
  - Without CDSS: 10 minutes to half an hour

CDSS: Clinical Decision Support System

Possible Disadvantages of CDSS

- Changing relation between patient and the physician
- Limiting professionals' possibilities for independent problem solving
- Legal implications - with whom does the onus of responsibility lie?

Evaluation Results

- HEALS has served in Taipei City Hospital for more than 40000 cases.
- Time of editing a report markedly decreased from 20 minutes to 5 minutes per case
- The ratio of customer complaints about the health reports was decreased to nearly zero

Perspective of HEALS

- To be one of the references of health examination information systems
- Future improvement of the CDSS in HEALS
  - Analyze the database to extract stochastic or domain-specific methods to improve healthcare quality and efficacy

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The Decision Support System Used in HEALS (Health Examination Automatic Logic System)

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Clinical Diagnosis

- Infer a disease state that is not directly observable
- Forms of a physician's knowledge:
  - Rule
  - Pattern

Knowledge-Based Agents

- **Knowledge base**
  - The center component
  - A set of sentences (rules)
    - Knowledge representation language
- **Inference**
  - Reasoning engine

Define the Task Environment of an Intelligent Agent

- **PEAS**
  - Performance measure
  - Environment
  - Actuators
  - Sensors

Define the Task Environment
- Performance Measure

- Minimizing error
- Minimizing operating time
- Maximizing quality
- Maximizing reports output
  - Over 6000 reports per year now

Define the Task Environment **- Environment**

- **Known examination items**
  - Physical examinations
  - Laboratory tests
  - Others
- **Known examination types**
  - Laboratory
    - Numerical (glucose, liver function, …)
    - Symbolic (hepatitis markers, …)
  - Others
    - Text (gastroenteroscopy, …)

Define the Task Environment
- Actuators

- Output the diagnoses
  - Possible diseases
- Output the suggestions
  - Life style modification
  - Medical suggestion

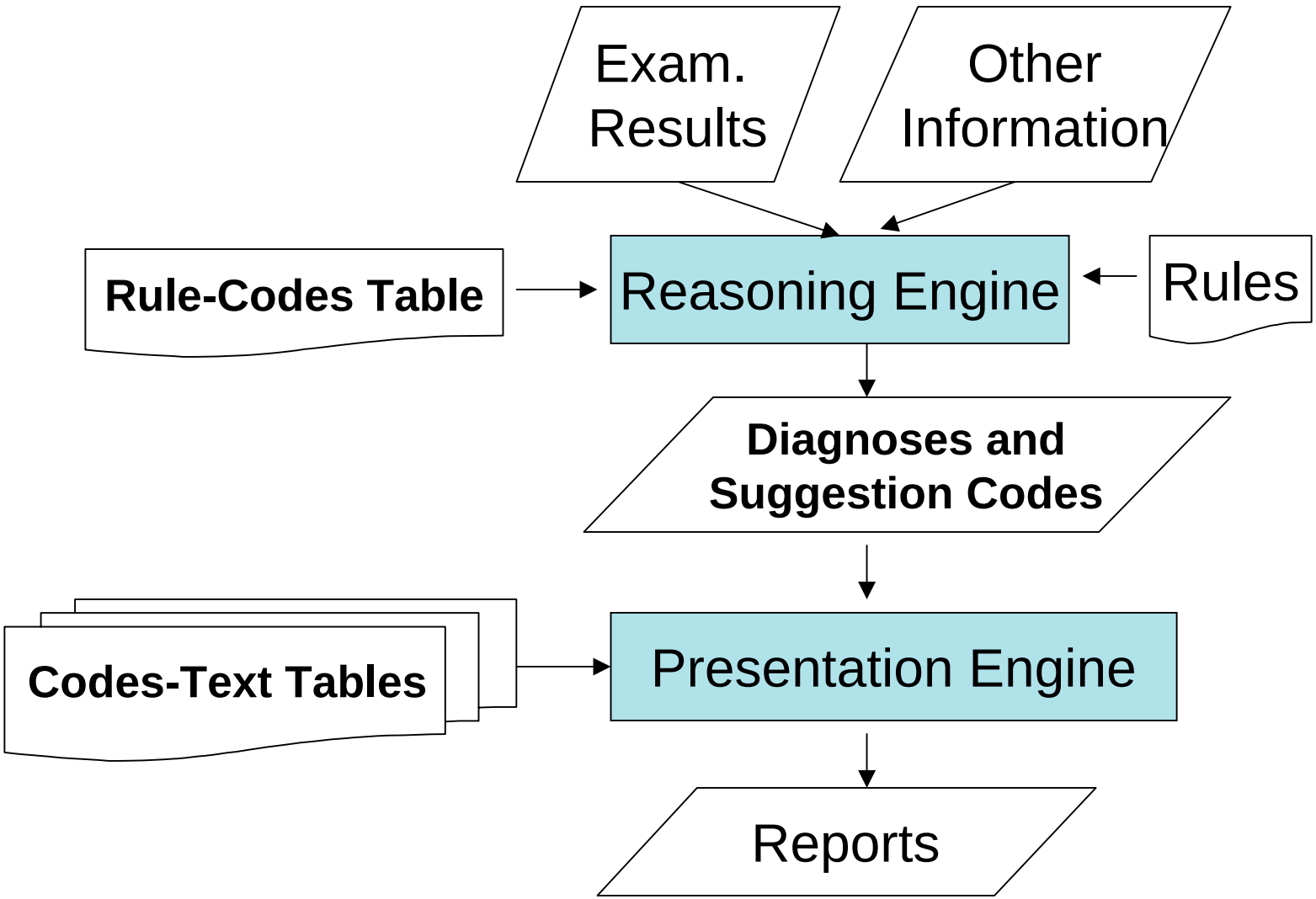
Define the Task Environment
- Sensors

- Examination results
  - From database system
- Personal Health History

CDSS of HEALS

CDSS: Clinical Decision Support System

Algorithm


Exam. Results
Other Information
Rule-Codes Table
Reasoning Engine
Rules
Diagnoses and Suggestion Codes
Codes-Text Tables
Presentation Engine
Reports

Rule-Codes Table

Rule Name	Description	Section Code	Suggestion codes
MCVLHBN1	Low MCV, normal HB, MCV/RBC>13	1	d20,602,g24r1,t84
MCVLHBN2	(r/o Thalassemia) Low MCV, normal HB	1	d20,G24R2,t82
MCVLHBL1	(Microcytic anemia) low MCV, low HB, MCV/RBC>13	1	G24R2,t83
MCVLHBL2	(r/oThalassemia) low MCV, low HB, MCV/RBC<13	1	d20,G24R2,t81
MCVNHBL1	Normal MCV, HB10-12	1	t10,d50,40,403,g24r1
MCVNHBL2	Normal MCV, HB<10	1	t11,d50,40,403,g24r1

Code-Text Table: Diagnoses

Code	Diagnosis
81	r/o Thalassemia
82	r/o Thalassemia
83	Microcytic anemia
84	Low MCV

Code-Text Table: Suggestion

601	目前不需治療
601e	No medical treatment required at the moment.
602	疑帶有地中海型貧血基因
602e	It is suspected that you have a thalassemia gene.
603	因無明顯分類異常或伴隨其他血球變化，可觀察
603e	No marked classification abnormality is found concurrently with any other pathological change in blood cells, thus no medical treatment is required at the moment.
604	疑因過敏體質所致,
604e	No medical treatment is required, as the disorder is caused by an irritable body.
605	正值發育期間的小孩及青少年，其值常見偏高,
605e	The value is usually relatively high among kids and teenagers who grow rapidly.

BNF Grammar of Rules

```
declaration ::= limit_declaration
  | range_declaration
  | clause_declaration
  | rule_declaration
```

BNF: Backus-Naur Form

Full text on:
http://www.csie.ntu.edu.tw/~d93009/AMIA2006/

BNF Grammar of Rules (cont.)

```
limit_declaration ::= limitdef
  limit_name limit
range_declaration ::= rangedef
  range_name range
clause_declaration ::=
  clausedef clause_name clauses
rule_declaration ::= ruledef
  rule_name rules
```

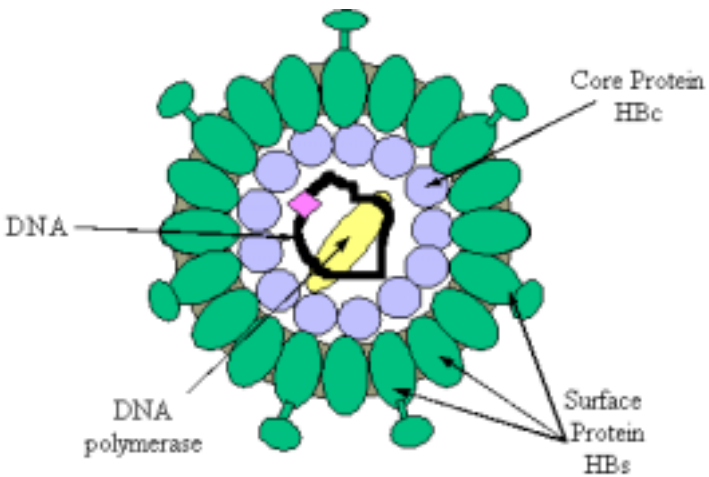
Examples of Rules

```
limitdef     UWBC2    UWBC     >    20

rangedef     UWBC1    UWBC     (5    20]

clausedef    UWBC6    UWBC2 || UWBC4

ruledef      UWBCABNH  UWBC1 &&
  URBCN && !URBC4
```

Reasoning Engine

- Forward chaining reasoning
  - Data-driven reasoning
- Procedural approach part of this implementation
  - Initiation of variables used in rules
- Processing rules
- Generating result codes

Examples of Encoding Domain Knowledge into Rules



- Some Hepatitis B Markers
  - Hepatitis B surface antigen (HBsAg)
    - Outer surface coat
  - Hepatitis B surface antibody (HBsAb)
    - Antibody to HBsAg
  - Hepatitis B core antibody (HBcAb)
    - Antibody to inner nucleocapsid core

Interpretation of Hepatitis B Markers

```
limitdef    HBSAG_pos   HBSAG   ==  "+“
** HBsAg is positive

limitdef    HBSAG_neg   HBSAG   ==  "-“
** HBsAg is negative

limitdef    HBSAB_pos   HBSAB   ==  "+“
** HBsAb is positive

limitdef    HBSAB_neg   HBSAB   ==  "-“
** HBsAb is negative
```

Interpretation of Hepatitis B Markers

```
limitdef    HBCAB_pos   HBCAB   ==  "+“
** HBcAb is positive

limitdef    HBCAB_neg   HBCAB   ==  "-“
** HBcAb is negative
```

Interpretation of Hepatitis B Markers

```
limitdef    OLD_HBSAG_pos   OLD_HBSAG   ==  "+“
** any of the previous HBsAg tests is positive

limitdef    OLD_HBSAG_neg   OLD_HBSAG   ==  "-“
** all of the previous HBsAg tests are negative

limitdef    OLD_HBSAB_pos   OLD_HBSAB   ==  "+“
** any of the previous HBsAb tests is positive

limitdef    OLD_HBSAB_neg   OLD_HBSAB   ==  "-“
** all of the previous HBsAb tests are negative
```

Interpretation of Hepatitis B Markers

```
limitdef    OLD_HBCAB_pos   OLD_HBCAB
  ==  "+“
** any of the previous HBcAb tests is
  positive


limitdef    OLD_HBCAB_neg   OLD_HBCAB
  ==  "-“
** all of the previous HBcAb tests are
  negative
```

Interpretation of Hepatitis B Markers

```
ruledef  HBSAG_nil   !HBSAG_pos && !HBSAG_neg
** If HBsAg is not tested

ruledef  HBSAB_nil   !HBSAB_pos && !HBSAB_neg
** If HBsAb is not tested

ruledef  HBCAB_nil   !HBCAB_pos && !HBCAB_neg
** If HBcAb is not tested

ruledef  HBCAB_diff  HBCAB_neg && OLD_HBCAB_pos
** If HBcAb is negative now and any of the
   previous HBcAb tests is positive
```

Interpretation of Hepatitis B Markers

```
ruledef  HBV_nnn  HBSAG_neg && HBSAB_neg &&
   HBCAB_neg && !AGE_50

** If HBsAg is negative, HBsAb is negative, HBcAb
   is negative, and age is less than 50
```

Interpretation of Hepatitis B Markers

```
ruledef  HBV_nnn  HBSAG_neg && HBSAB_neg &&
   HBCAB_neg && !AGE_50
```

HBsAg: negative; Anti-HBs: negative; Anti-HBc: negative

- You have never got hepatitis B infection, thus it is recommended that you receive vaccine injections.
- Please visit the Outpatient Clinic of Family Medicine Division for a follow-up diagnosis and treatment.

Interpretation of Hepatitis B Markers

```
ruledef      HBV_pnp      HBSAG_pos &&
  HBSAB_neg &&  HBCAB_pos

** If HBsAg is positive, HBsAb is
  negative, and HBcAb is positive
```

Interpretation of Hepatitis B Markers

```
ruledef     HBV_pnp     HBSAG_pos &&  HBSAB_neg &&
  HBCAB_pos
```

HBsAg: positive; Anti-HBs: negative; Anti-HBc: positive

- Don't take medication without a physician's instructions, so as to avoid augmenting the workload of liver.
- Take a rest, as appropriate; avoid being physically and mentally exhausted.
- You are a hepatitis B carrier. Please have a follow-up consultation in the Outpatient Clinic every half a year.

Interpretation of Hepatitis B Markers

```
ruledef     HBV_nn      HBSAG_neg &&  HBSAB_neg
  &&  HBCAB_nil &&  !AGE_50

** If HBsAg is negative, HBsAb is negative,
  HBcAb is not tested, and age is less than 50
```

Interpretation of Hepatitis B Markers

```
ruledef      HBV_nn       HBSAG_neg &&  HBSAB_neg &&
   HBCAB_nil &&  !AGE_50
```

HBsAg: negative; Anti-HBs: negative

- Your antibody test is negative.

  It is recommended that you go to the
  OPD and pay for a test for core antibody.
  If the subsequent test is negative again,
  you may consider receiving vaccine injections.
- Please visit the Outpatient Clinic of
  Family Medicine Division for a follow-up
  diagnosis and treatment.

Interpretation of Hepatitis B Markers

```
ruledef     HBV_nnp1    HBSAG_neg &&  HBSAB_neg
  &&  HBCAB_pos &&  OLD_HBSAG_pos

** If HBsAg is negative, HBsAb is negative,
  HBcAb is negative, and any of the previous
  HBsAb tests is positive
```

Interpretation of Hepatitis B Markers

```
ruledef     HBV_nnp1    HBSAG_neg &&  HBSAB_neg &&
  HBCAB_pos &&  OLD_HBSAG_pos
```

HBsAg: negative; Anti-HBs: negative; Anti-HBc: positive; Previous HBsAg: positive

- Do not take medication without physician's instructions, to avoid augmenting the workload of liver.
- Take a rest, as appropriate; avoid being physically and mentally exhausted.
- You are a hepatitis B carrier. Please have a follow-up consultation in the Outpatient Clinic every half a year.

Examples of Encoding Domain Knowledge into Rules

- Anemia
  - RBC (Red Blood Cell)
  - MCV (Mean Corpuscle Volume)
  - Hb (Hemoglobin)

Anemia

```
rangedef    MCV_Low78      MCV [78  80)
rangedef    MCV_Low        MCV (0   80)
rangedef    HB_N           HB  [12  19]
rangedef    HB_Low         HB  (0   12)
rangedef    HB_mildLow     HB  [10  12)
rangedef    HB_severeLow   HB  (0   10)
limitdef    HB_High        HB  > 19
limitdef    RBC_High       RBC > 7
limitdef    RBC_mildHigh   RBC > 5
```

Anemia

```
rangedef    MCV_DIV_RBC_Low   MCV_DIV_RBC (0   13)
** MCV/RBC > 0, and < 13

limitdef    AGE_YOUNG     AGE     < 21
** age less than 21

ruledef     MCVABNL21    AGE_YOUNG && MCV_Low78 &&
  HB_N
** If age less than 21, MCV>=78 and <80, and Hb is
  normal
```

Anemia

```
ruledef     MCVLHBN2      !MCVABNL21 && MCV_Low && HB_N
   && MCV_DIV_RBC_Low

** If MCVABNL21 is false,  MCV<80, Hb is normal, and
   MCV/RBC<13 (r/o Thalassemia carrier)
```

Anemia

```
ruledef     MCVLHBN2     !MCVABNL21 && MCV_Low && HB_N
   && MCV_DIV_RBC_Low
```

RBC: 6.00*10^6/ul, Hb: 12.8g/dL, MCV: 63fl

r/o Thalassemia carrier

- To be under observation. Please visit the Outpatient Clinic of Family Medicine Division for a follow-up diagnosis and treatment, in the event of doubts or discomfort.

Anemia

```
ruledef     MCVLHBL1     !MCVABNL21 && MCV_Low && HB_Low
   && !MCV_DIV_RBC_Low

** If MCVABNL21 is false,  MCV<80, Hb<12, and
   MCV/RBC>=13 (microcytic anemia)
```

Anemia

```
ruledef     MCVLHBL1     !MCVABNL21 && MCV_Low && HB_Low
   && !MCV_DIV_RBC_Low
```

RBC: 3.00*10^6/ul, Hb: 8.0g/dL, MCV: 70fl

Microcytic anemia

- Please visit the Outpatient Clinic of Division of Family Medicine for a follow-up diagnosis and treatment.

Anemia

```
ruledef     MCVLHBL2      !MCVABNL21 && MCV_Low && HB_Low
   && MCV_DIV_RBC_Low

** If MCVABNL21 is false,  MCV<80, Hb<12, and MCV/RBC<13
   (Thalassemia)
```

Anemia

```
ruledef     MCVLHBL2     !MCVABNL21 && MCV_Low && HB_Low &&
   MCV_DIV_RBC_Low
```

RBC: 6.00*10^6/ul, Hb: 10.0g/dL, MCV: 62fl

r/o Thalassemia

- Please visit the Outpatient Clinic of Division of Family Medicine for a follow-up diagnosis and treatment.

Anemia

```
ruledef     MCVNHBL2     !MCV_Low && HB_severeLow

** If MCV>=80 and Hb<10
```

Anemia

ruledef MCVNHBL2 !MCV_Low && HB_severeLow

RBC: 3.00*10^6/ul, Hb: 8.0g/dL, MCV: 82fl

Anemia

- Have a balanced diet, taking in all sorts of nutrients, avoid partiality for a particular kind of food; take sufficient amount of vitamins.
- Refrain from blood donation.
- Please visit the Outpatient Clinic of Division of Family Medicine for follow-up diagnoses and treatments.

Summary and Conclusion

HEALS: Advantages

- Provide services beyond the territory boundary between rural and urban medical settings
- Improve the quality of health examination information flow.
- Improve the efficiency of health examination information flow.
- Reduce the mundane daily work of clinical workers
- Provide education for junior doctors
- Eliminate common misses in health reports

CDSS of HEALS: Advantages

- A way of using clinical guidelines in medical practices.
- Simple and clear rule syntax
- Efficient reasoning algorithm
- To ensure the state-of-the-art of the knowledge base, the rules can be readily updated by domain experts easily

Evaluation Results

- HEALS has served in Taipei City Hospital for more than 40000 cases.
- Time of editing a report markedly decreased from 20 minutes to 5 minutes per case
- The ratio of customer complaints about the health reports was decreased to nearly zero

HEALS: Next

- To be one of the references of health examination information systems
- Future improvement of the CDSS in HEALS
  - Analyze the database to extract stochastic or domain-specific methods to improve healthcare quality and efficacy

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