

Arden Syntax: Wissensrepräsentation und -verarbeitung in der Medizin

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Computers in clinical medicine—steps of natural progression

- step 1: patient administration
 - admission, transfer, discharge, and billing of medical services
 - step 2: computerized documentation of patients' medical data
 - electronic health record: life-long, multimedia
 - **step 3: patient data retrieval and analysis at the medical institution**
 - data warehouse, research databases, study support systems
 - quality assurance and reporting
 - **step 4: knowledge-based software systems for clinical decision support**
 - safety net, quality assurance and improvement:
 - ... for the **individual patient**
 - ... and the physician
 - ... and the medical institution
-

Clinical medicine: high complexity

- **sources of medical knowledge**
 - definitional
 - causal
 - statistical
 - heuristic
- **layers of medical knowledge**
 - observational and measurement level
 - interpretation, abstraction, aggregation, summation
 - pathophysiological states
 - diseases/diagnoses, therapies, prognoses, patient management
- **imprecision, uncertainty, and incompleteness**
 - imprecision (=fuzziness) of medical concepts
 - * due to the unsharpness of boundaries of linguistic concepts
 - uncertainty of medical conclusions
 - * due to the uncertainty of the occurrence and co-occurrence of medical concepts
 - incompleteness of medical data and medical knowledge
 - * due to only partially known data and partially known explanations for medical phenomena
- **huge amount of medical data and medical knowledge**
 - patient history, physical examination, laboratory test results, clinical findings
 - symptom-disease relationships, disease-therapy relationships, ...
 - terminologies, ontologies: SNOMED CT, LOINC, UMLS, ...



specialization, teamwork, quality management, **computer support**

Clinical decision support systems

<p>diagnostic support</p> <ul style="list-style-type: none"> • clinical alerts, reminders, calculations • data interpretation, (tele)monitoring • differential diagnostic consultation <ul style="list-style-type: none"> – rare diseases, rare syndromes – further or redundant investigations – pathological signs accounted for • consensus-criteria-based evaluation <ul style="list-style-type: none"> – definitions – classification criteria 	<p>therapy advice</p> <ul style="list-style-type: none"> • drug alerts, reminders, calculations <ul style="list-style-type: none"> – indication, contraindications, redundant medications, substitutions – adverse drug events, interactions, dosage calculations, consequent orders • management of antibiotics therapy • (open-loop) control systems
<p>prognostic prediction</p> <ul style="list-style-type: none"> • illness severity scores, prediction rules • trend detection and visualization 	<p>patient management guidelines</p> <ul style="list-style-type: none"> • guideline-based reminders • computerized clinical guidelines, protocols, SOPs • high-level patient and hospital analytics

**Arden-Syntax-based,
service-oriented clinical decision support**

Arden Syntax and Health Level Seven (HL7)

- A standard language for writing situation-action rules that can trigger alerts based on abnormal clinical events detected by a clinical information system.

van Bommel, J.H., Musen, M.A. (eds.) (1997)
Handbook of Medical Informatics, Springer-Verlag,
Heidelberg, Glossary, p. 559.

- Each module, referred to as a **Medical Logic Module (MLM)**, contains sufficient knowledge to make a single decision.
extended by packages of MLMs for complex clinical decision support
 - Contraindication alerts, management suggestions, data interpretations, treatment protocols, and diagnosis scores are examples of the health knowledge that can be represented using MLMs.
extended by single and differential diagnostic support, temporal monitoring, control systems, computerized processing of clinical pathways and management guidelines
 - The first version of the Arden Syntax (draft prepared at the Arden Homestead, New York, in 1989) was administered and issued by the American Society for Testing and Materials ASTM (1992, version 1.0; **today 2.8, towards 2.9**). Since 1998, an Arden Syntax Working Group is part of the HL7 organization (www.hl7.org).
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Content

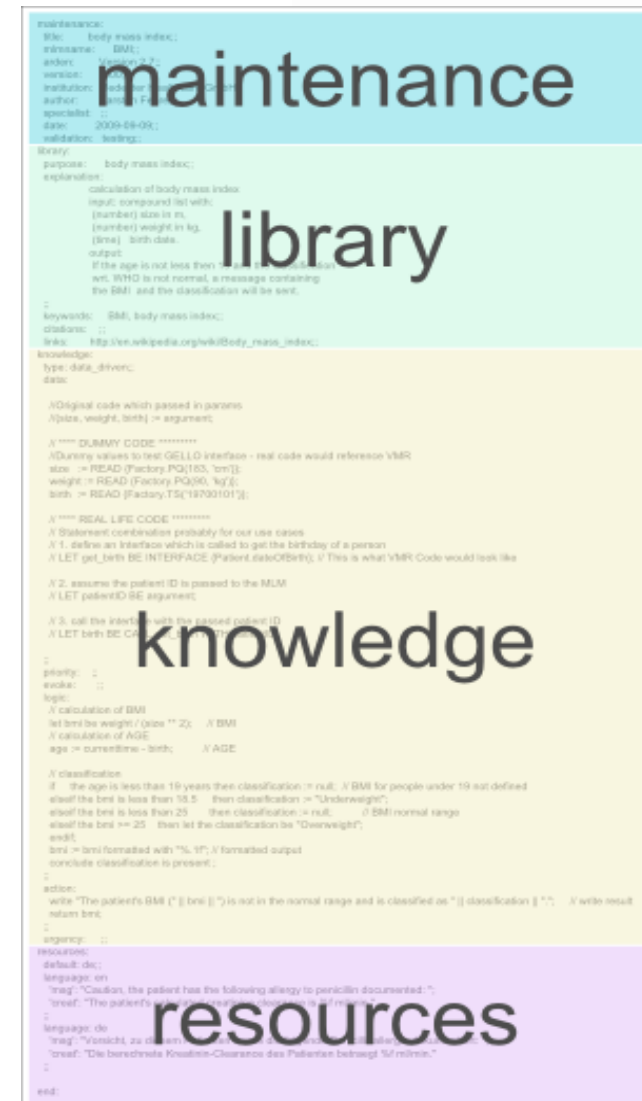
- **Arden Syntax – General Information**
 - **General MLM Layout**
 - Maintenance Category
 - Library Category
 - Knowledge Category
 - Resources Category
 - **Identify an MLM**
 - **Data Types**
 - **Operators**
 - Basic Operators
 - Curly Braces
 - List Operators
 - Logical Operators
 - Comparison Operators
 - String Operators
 - Arithmetic Operators
 - Other Operators
 - **Control Statements**
 - **Call/Write Statements and Trigger**
-

General MLM layout

- An MLM is composed of slots grouped into four required **categories: maintenance, library, knowledge, and resources.**
- A category starts with its name followed immediately by a colon (e.g., maintenance:).
- Categories must appear in the correct order.
- Within each category is a set of **slots.**
- Slots must appear in the correct order, too.
- In general, an MLM is arranged such as:

```

maintenance:
  slotname: slot-body;;
  slotname: slot-body;;
  ...
library:
  slotname: slot-body;;
  ...
knowledge:
  slotname: slot-body;;
  ...
resources: <optional>
  slotname: slot-body;;
  
```



```

maintenance:
  slotname: slot-body;;
  slotname: slot-body;;
  ...
library:
  slotname: slot-body;;
  ...
knowledge:
  slotname: slot-body;;
  ...
resources: <optional>
  slotname: slot-body;;
  
```

Sample MLM

- Most of the examples for operator and concept explanation are taken from the following sample MLM which calculates the body mass index (BMI) of a patient

```
maintenance:
  title: simple body mass index;;
  mlmname: BMI_HowTo;;
  arden: Version 2.7;;
  version: 1.00;;
  institution: Medexter Healthcare GmbH;;
  author: Karsten Fehre;;
  specialist: ;;
  date: 2010-09-09;;
  validation: testing;;
library:
  purpose: body mass index;;
  explanation: calculation of body mass index;;
  keywords: BMI, body mass index;;
  citations: ;;
  links: http://en.wikipedia.org/wiki/Body\_mass\_index;;
```

Sample MLM (cont.)

```
knowledge:
  type: data_driven;;
  data:

    // MLM that contains the interface definition "LET get_birth BE INTERFACE {Patient.dateOfBirth}; "
    mlmImport      := MLM 'interface_birthday_definition';

    // include
    include mlmImport;

    mlmForReadSize := MLM 'read_Size_MLM'; // MLM which can read the current size of the patient from the DB

    LET patientID BE argument; // the patient ID is passed to the MLM

    LET birth      BE CALL get_birth WITH patientID; // call the interface with the passed patient ID

    // read all measured weights from the database
    LET weights    BE READ {SELECT measured_weight FROM DB WHERE patID = patientID };

    LET userEvent BE EVENT {getBMI};

    // object declaration
    bmiResult := object [bmi, classification];

    ;;
    priority: ;;
    evoke:
      userEvent;
    ;;
```

Sample MLM (cont.)

```
logic:
  result := new bmiResult; // create an empty result object

  weight := latest of weights; // get the latest weight from the list

  size := call mlmForReadSize with patientID; // get the size of the patient calculated by another MLM

  result.bmi := weight / (size ** 2); // calculation of BMI
  age := currenttime - birth; // calculation of AGE

  // classification - the classification is only valid for patients older than 19
  if the age is less than 19 years then result.classification := null;
  elseif the result.bmi is less than 18.5 then result.classification := localized 'under';
  elseif the result.bmi is less than 25 then result.classification := null;
  else let the result.classification be localized 'over';
  endif;

  result.bmi := result.bmi formatted with localized 'msg'; // construct the localized message

  if (time of weight) is before (currenttime - 6 months) then
    conclude false; //no bmi calculation if the latest measure was 6 months ago
  else
    conclude result.classification is present ; // if there is a classification, execute the action slot
  endif;

;;
```

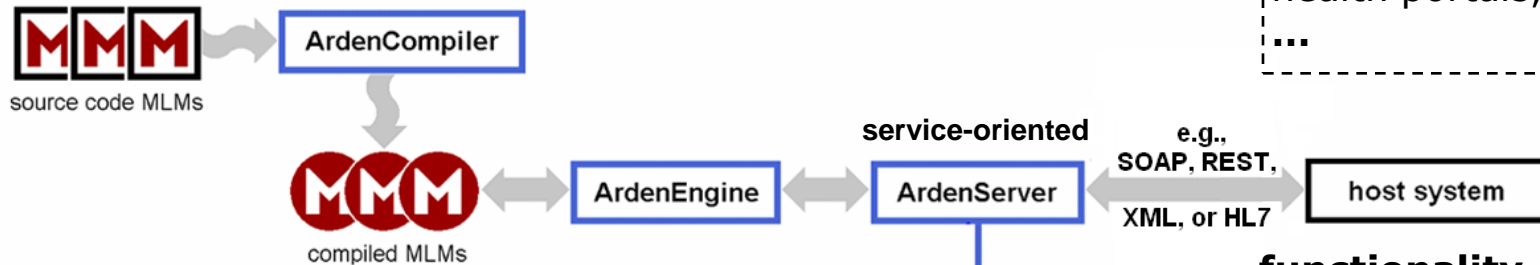
Sample MLM (cont.)

```
action:
  write result.bmi || result.classification || "."; // return result
  return result;
;;
urgency: ;;
resources:
  default: de;;
  language: en
    'msg' : "The patient's BMI %.1f is not in the normal range and is classified as ";
    'under' : "Underweight";
    'over' : "Overweight"
  ;;
  language: de
    'msg' : "Der BMI %.1f des Patienten ist nicht im normalen Bereich und wird klassifiziert als ";
    'under' : "Untergewicht";
    'over' : "Übergewicht"
  ;;
end:
```

Arden Syntax, Arden Syntax server, and health care information systems

integration

HIS, MIS, PDMS, LIS,
medical practice SW,
web-based EHR,
telemedicine
applications,
health portals,
...



* data & knowledge services center

operational:

- harmonized input data
- Arden Syntax MLMs
- collected reasoning data

exploratory:

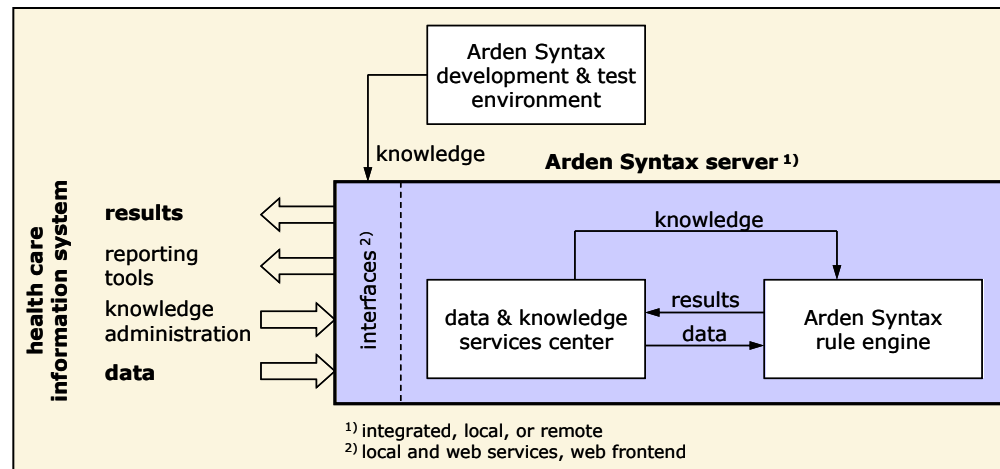
- rule learning/tuning
- data and concept mining

functionality

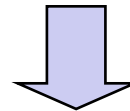
reminders and alerts,
monitoring,
surveillance,
diagnostic and
therapeutic decision
support,
...

Arden Syntax server and software components

- Arden Syntax integrated development and test environment (IDE) including
 - Medical logic module (MLM) editor and authoring tool
 - Arden Syntax compiler (syntax versions 2.1, 2.5, 2.6, 2.7, and 2.8)
 - Arden Syntax engine
 - MLM test environment
 - MLM export component
- command-line Arden Syntax compiler



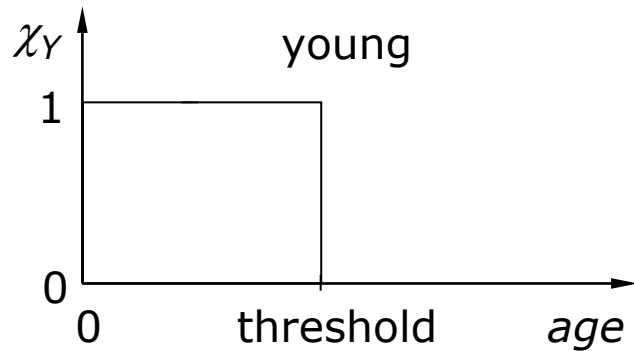
- web-services-based Arden Syntax server including
 - Arden Syntax engine
 - MLM manager
 - XML-protocol-based interfaces, e.g., SOAP, REST, and HL7
 - a project-specific data and knowledge services center may be hosted
- Java libraries
 - Arden Syntax compiler
 - Arden Syntax engine



Fuzzy Arden Syntax

- extension to fuzzy sets, operators, statements, and parallel execution

Crisp sets vs. fuzzy sets



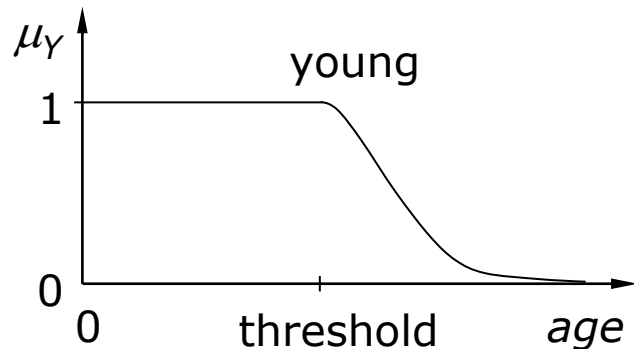
yes/no decision

$$U = [0, 120]$$

$$Y \subseteq U \text{ with } Y = \{(\chi_Y(x)/x) \mid x \in U\}$$

$$\chi_Y: U \rightarrow \{0, 1\}$$

$$\chi_Y(x) = \begin{cases} 0 & x > \text{threshold} \\ 1 & x \leq \text{threshold} \end{cases} \quad \forall x \in U$$



gradual transition

$$U = [0, 120]$$

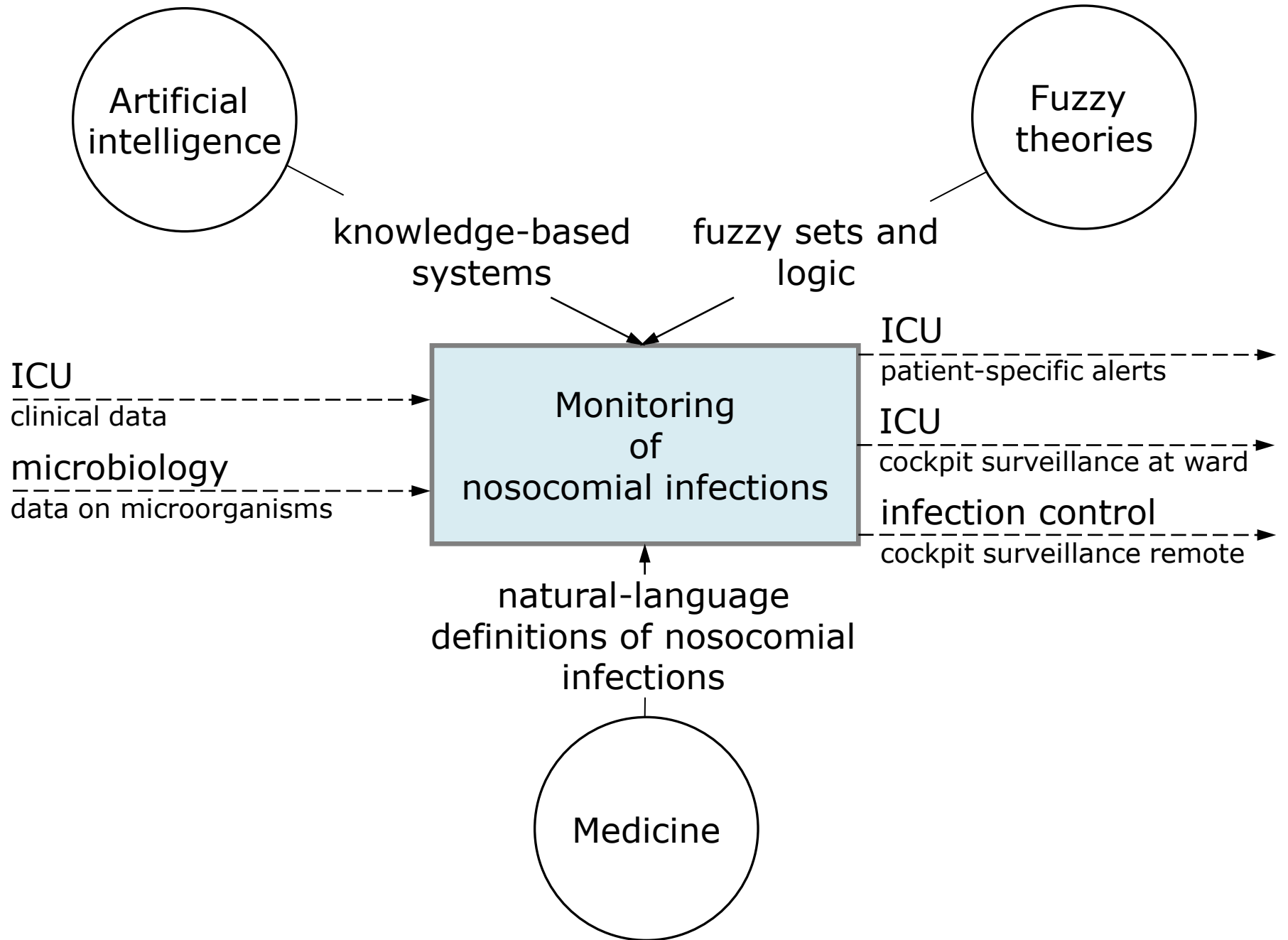
$$Y \subseteq U \text{ with } Y = \{(\mu_Y(x)/x) \mid x \in U\}$$

$$\mu_Y: U \rightarrow [0, 1]$$

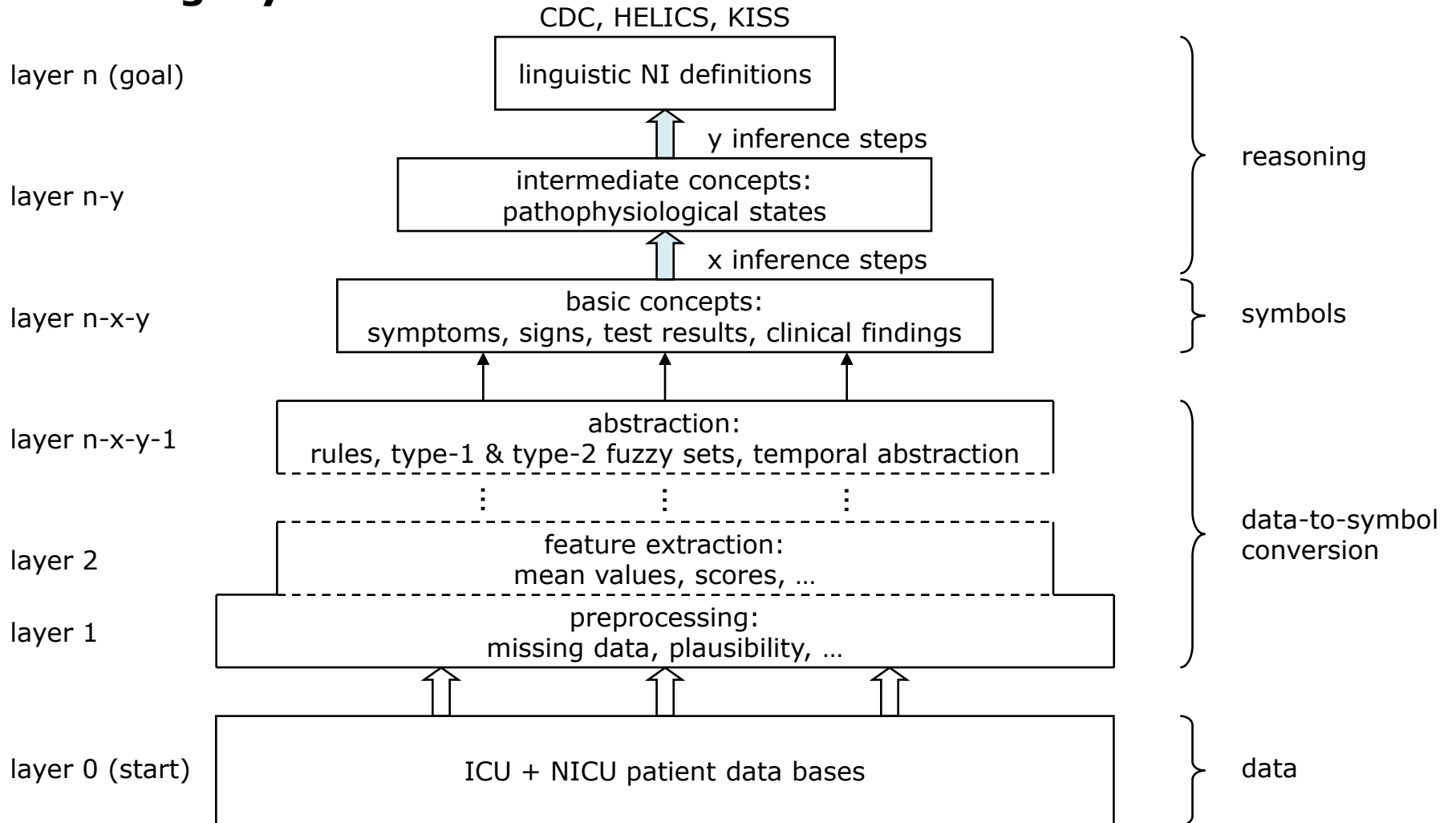
$$\mu_Y(x) = \begin{cases} \frac{1}{1 + (0.04 x)^2} & x > \text{threshold} \\ 1 & x \leq \text{threshold} \end{cases} \quad \forall x \in U$$

Moni/Surveillance-ICU

knowledge-based early recognition and automated monitoring of hospital-acquired infections in intensive care units with adult patients

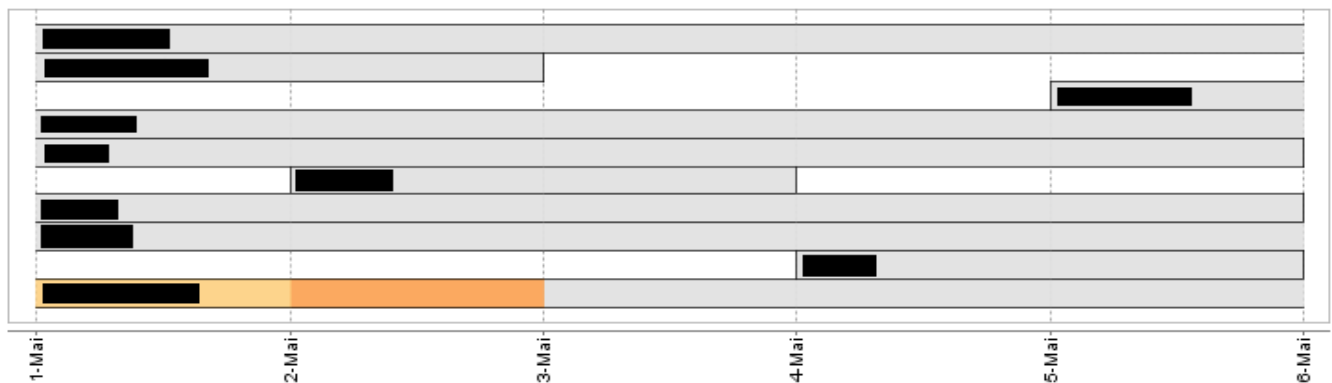


Processing layers



von 2008-05-01 bis 2008-05-05 Anzeigen Standardansicht Grafik ausblenden fixe Tabellenbreite

13c3



Aufenthalt
 10% - 50%
 50% - 90%
 90% - 100%

- Stationen/Patienten
- 13b1
 - 13b3
 - 13c1
 - 13c2
 - 13c3
 - 13h1
 - 13h3
 - 13i1

2008-05-10

2008-05-09

2008-05-08

2008-05-07

2008-05-06

2008-05-05

2008-05-04

2008-05-03

2008-05-02

2008-05-01

Messwerte

Interpretationen und Diagnosen

CRI2 (generalisierte ZVK-assoz. Infektion)	80 %	
Fieber	80 %	
Hypotonie	80 %	
klin. Anzeichen für Entzündung bei HWI	80 %	
klin. Anzeichen für Entzündung bei Sepsis	80 %	
CRP erhöht	37 %	
Schock	100 %	
max. Körpertemperatur	37,4 °C	
Blutdruck-Profil (unterer Grenzwert)	86 mmHg	
Blutdruck-Profil (oberer Grenzwert)	88,33 mmH...	
Blutdruck-Profil (21:00 (Vortag) bis 3:00)	86,11 mmH...	
Blutdruck-Profil (0:00 bis 6:00)	85,89 mmH...	
Blutdruck-Profil (3:00 bis 9:00)	89,67 mmH...	
Blutdruck-Profil (6:00 bis 12:00)	93,83 mmH...	

CRI2 (generalisierte ZVK-assoz. Infektion)

UND	80 %
NICHT	100 %
pos. Blutkultur	
klin. Anzeichen für Entzündung bei Sepsis	80 %
ODER	100 %
quant. Kultur Katheterspitze	100 %
semiquant. Kultur Katheterspitze	100 %

klin. Anzeichen für Entzündung bei Sepsis

ODER	80 %
Fieber	80 %
Hypotonie	80 %
Leukopenie	
Leukocytose	
CRP erhöht	37 %

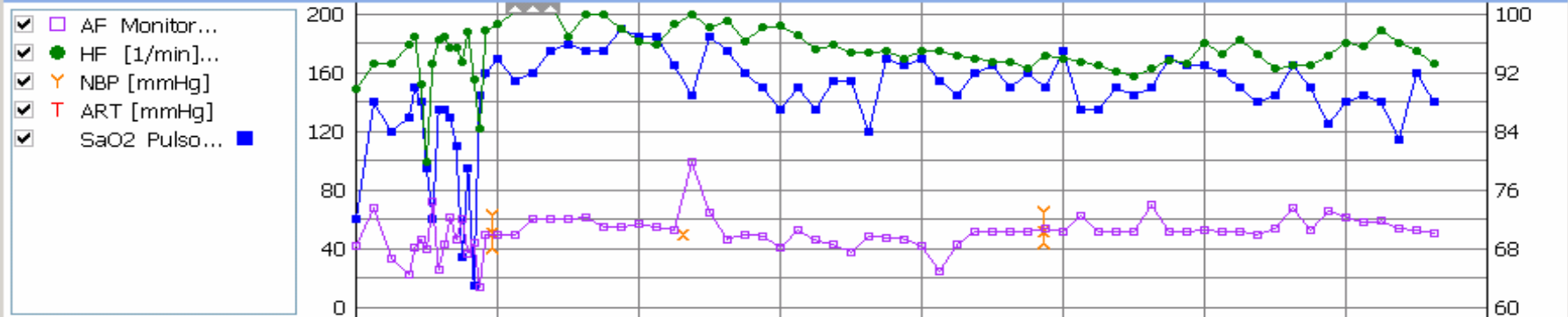
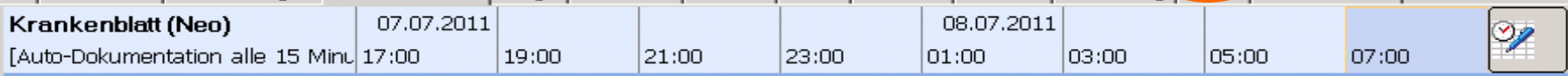
Hypotonie

ODER	100 %
Blutdruck-Abfall	
Schock	100 %

Schock

Schockindex	0,8
-------------	-----

- Krankenblatt (Ne)
- Krankenblatt (Neo)
- Grafik
- Vitalparame...
- Ereignis
- Leistungen
- Beatmung
- Blutgase
- Medikamente
- Perfusoren
- Einfuhr
- Ausfuhr
- Bilanz
- Kath/Drains
- GI
- CAPD
- Pflege
- N-PASS
- Neuro
- Labor Stat.
- Labor

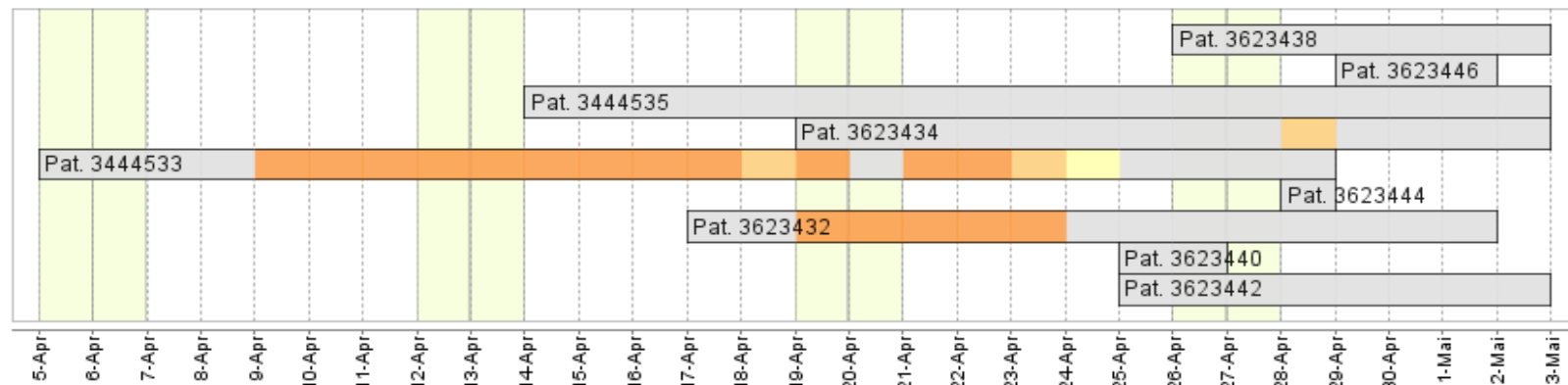


HF [1/min]	189	190	191	170	172	167	172	166
Puls [1/min]	189	190	191	170	181	168	172	167
AF Monitor [1/min]	50	55	49	47	54	52	66	51
ART [mmHg]								
NBP [mmHg]	63/41 (51)		/ (50)		65/44 (52)			
SaO2 Pulsoxym. [%]	92	98	90	93	90	93	85	88
SaO2 Messort								
Ta [°C]	37,3	37,6	37,6	36,8	36,9	37,4	36,9	36,4
Temp [°C]								
Hautfarbe (Neo)								
Stamm (Neo)								
Summe Urin (24h)								
Summe Windel (24h)								
Summe Einfuhr (24h)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Summe Ausfuhr (24h)								
Nettobilanz (24h)	0	0	0	0	0	0	0	0

Moni dashboard: Temporal course of infection episodes in ICU patients

von 2008-04-01 bis 2008-05-04 Anzeigen Standardansicht Grafik ausblenden fixe Tagesbreite

Dep. 21



Stationen/Patienten	
Dep. 21	
Pat.	3623438
Pat.	3623446
Pat.	3444535
Pat.	3623434
Pat.	3444533
Pat.	3623444
Pat	3623432

Clinical decision support with Arden Syntax

- CDS platforms
 - based on Arden Syntax and Fuzzy Arden Syntax
 - * with data (sometimes) and knowledge services center and extended interoperability (web-services, XML data interfaces, libraries)
 - integrated into or interconnected with
 - CareVue and ICIP PDMSs (by Philips)
 - * monitoring and reporting of ICU-acquired infections (ICUs and NICUs)
 - ICM (by Dräger)
 - * ICU decision support modules (Universitätsklinikum Erlangen)
 - i.s.h.med HIS (by Siemens AG)
 - * dosing of immunosuppressive drugs for kidney transplant patients
 - * prediction of metastases in melanoma patients
 - * standard operating procedures for chemotherapy treatment of melanoma patients
 - medico//s HIS (by Siemens AG)
 - * laboratory-based clinical reminders
 - Soarian HIS (by Siemens AG) and Orbis HIS (by Agfa)
 - * hepatitis serology test interpretation
 - VistA HIS (by Department of Veterans Affairs)
 - * service-oriented, standards-based CDS (clinical reminders and patient report cards)
 - Possible adverse drug events (FFG project with Salzburger Universitätsklinikum)
 - Teleiatros, iPhone, iPad
 - * remote CDS, mHealth
-