Arden Syntax and fuzzy medical linguistic concepts in Fuzzy Arden Syntax

An introduction

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Arden Syntax

- Knowledge representation standard capable of the computerized representation of medical knowledge

- Medical rule encoding in a syntax resembling natural language
  - Code better understandable
  - Code easier verifiable

- Units of knowledge are called medical logic modules (MLMs)

## History

<table>
<thead>
<tr>
<th>Version</th>
<th>Year</th>
<th>Important changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>2002</td>
<td>new string operators; reserved word “currenttime” returns the system time</td>
</tr>
<tr>
<td>2.5</td>
<td>2005</td>
<td>object capabilities: create and edit objects; XML representation of MLMs (except logic, action and data slot)</td>
</tr>
<tr>
<td>2.6</td>
<td>2007</td>
<td>UNICODE encoding; additional resources category to define text resources for specific languages; time-of-day and day-of-week data types; “localized” operator to access texts in specific languages</td>
</tr>
<tr>
<td>2.7</td>
<td>2008</td>
<td>enhanced assignment statement; extended “new” operator to allow easy and flexible object instantiation</td>
</tr>
<tr>
<td>2.8</td>
<td>2012</td>
<td>additional operators for list manipulation; operators to manipulate parts of given date and time values; switch statements; keyword “breakloop” for aborting a loop; number of editorial corrections</td>
</tr>
<tr>
<td><strong>2.9</strong></td>
<td>2013</td>
<td><strong>Fuzzy</strong>: fuzzy data types, fuzzy sets, and fuzzy logic; adjustment of all available operators to be able to handle fuzzy data types</td>
</tr>
<tr>
<td>2.10</td>
<td>2014</td>
<td>XML representation of MLMs (including logic, action and data slot)</td>
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</table>
Fuzzy logic

Traditional logic is bivalent, which means that only two truth values are allowed: every proposition must be either true or false. But the inherent vagueness of many terms, apparent in the sorites paradox, suggests that this requirement is too rigid if logic is to encompass the full scope and complexity of natural language.

Fuzzy logic has been developed, initially by the computer scientist Lofti Zadeh, to allow for imprecision and degrees of truth. Truth is presented as a continuum between true (1) and false (0). So, for instance, a particular proposition that is ‘partly true’ or ‘more or less true’ might be represented as true to degree 0.8 and false to degree 0.2. Fuzzy logic has been particularly important in AI (artificial intelligence) research, where ‘intelligent’ control systems need to be responsive to the imprecisions and nuances of natural language.

Fuzzy Arden Syntax: Modelling uncertainty in medicine

• linguistic uncertainty
  – due to the unsharpness (fuzziness) of boundaries in linguistic concepts; gradual transition from one concept to another
  – modeled by fuzzy sets (e.g., fever, increased glucose level, hypoxemia)

• propositional uncertainty
  – due to the incompleteness of medical conclusions; uncertainty in definitional, causal, statistical, and heuristic relationships
  – **here**: modeled by truth values between zero and one (e.g., 0.6, 0.9)
Medical concepts and guidelines

• Medical concepts are expressed in natural language
  • Often uncertain with respect to its meaning / range / boundaries
  • Subjective to individual interpretation, especially with comparative or subjective criteria

• Use case: ECDC definition of bloodstream infection

3.2 Bloodstream infection

• Patient has at least one positive blood culture for a recognised pathogen
  - or -
• Patient has at least one of the following signs or symptoms: fever (> 38 °C), chills, or hypotension and
  two positive blood cultures for a common skin contaminant (from two separate blood samples, usually within 48 hours).

• Chills, ICD-10
  • A sensation of cold that often marks the start of an infection and the development of a fever.
  • The sudden sensation of being cold. It may be accompanied by shivering.
Fuzzy sets

- Formalism to model classes with linguistic uncertainty, e.g., medical concepts
- Mathematical sets, whose elements have a truth value, expressed as a number between (and including) 0 and 1 (c.f., “normal”, or “crisp” sets, have a truth value of either 0 or 1)
- Each set has a membership function that determines the truth value of an element in the problem space with that set.

<table>
<thead>
<tr>
<th>Linguistic medical concept</th>
<th>Membership function</th>
<th>Fuzzy set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td>Temp. °C</td>
<td>Comp.</td>
</tr>
<tr>
<td>Katharina</td>
<td>37.3 °C</td>
<td>0</td>
</tr>
<tr>
<td>Julia</td>
<td>37.8 °C</td>
<td>0.6</td>
</tr>
<tr>
<td>Alexander</td>
<td>38.2 °C</td>
<td>1</td>
</tr>
</tbody>
</table>
Fuzzy logic

- Algebra used to evaluate logical combinations of concepts that are assigned a truth value, possibly with a truth value as result.

- Redefinition / extension of well-known logical operators
  - Negation
  - Conjunction
  - Disjunction
  - ...

- **Example:** ECDC clinical signs of blood stream infection

![Diagram showing disjunction of fever, hypotension, and chills]
Arden Syntax vs. Java ...

```java
import java.util.Locale;
import java.util.ResourceBundle;
import java.sql.*;
import java.text.MessageFormat;

public class sql_notification {

    // JDBC driver name and database URL
    static final String JDBC_DRIVER = "com.mysql.jdbc.Driver";
    static final String DB_URL = "jdbc:mysql://localhost/SIDEBS";

    // Database credentials
    static final String USER = "root";
    static final String PASS = "rootPassword";

    // Database Connection
    static Connection conn = null;

    private static boolean setupConnection() {
        boolean retual = true;
        try {
            // Register JDBC driver
            Class.forName(JDBC_DRIVER);
            // Open a connection
            conn = DriverManager.getConnection(DB_URL, USER, PASS);
            //Handle errors for Class.forName
            e.printStackTrace();
            retual = False;
        }
        return retual;
    }

    public static void main(String... args) throws Exception {
        final String sqlQuery = "SELECT temperature, heartRate, respRate, PaCO2, WBCCellCount, immatureBand " + "FROM sirsvalues WHERE IDPatient = testID;"
        if (setupConnection()) {
            Statement stmt = conn.createStatement();
            String sql = MessageFormat.format(sqlQuery, args[0]);
            ...
... and more Java.

```java
return;

// Execute a query
Statement stmt = conn.createStatement();
String sql = MessageFormat.format(sqlQuery, args[0]);

ResultSet rs = stmt.executeQuery(sql);

// Extract data from result set
while(rs.next()) {
    // Retrieve by column name
    int temperature = rs.getInt("temperature");
    int heartRate = rs.getInt("heartRate");
    int respRate = rs.getInt("respRate");
    int Pac02 = rs.getInt("Pac02");
    int wbccelCount = rs.getInt("wbccelCount");
    int immatureBand = rs.getInt("immatureBand");

    // Start - Checking SIRS criteria
    int counter = 0;
    if ((temperature > 38 || temperature < 36)
        counter++;
    if (heartRate > 90)
        counter++;
    if (respRate > 20 || Pac02 < 32)
        counter++;
    if ((wbccelCount > 12000 || wbccelCount < 4000) || immatureBand > 10)
        counter++;

    // End - Checking SIRS criteria

    // Refer to a properties file, one for each language
    Locale currentLocale = new Locale(args[1], args[2]);
    ResourceBundle messages = ResourceBundle.getBundle("MessagesBundle", currentLocale);

    if (counter >= 2)
        System.out.println(messages.getString("sirs_detected"));
    else
        System.out.println(messages.getString("no_sirs_detected"));
}
```
Fuzzy Arden Syntax

- Fuzzy constructs inherently supported by Arden Syntax version 2.9 and later

- Changes that facilitate fuzziness, e.g., for fuzzy sets
  - Incorporation of truth value data type and extension of the crisp truth value model to a fuzzy model
  - Incorporation of the fuzzy set data type
  - Extended syntax for automatic truth value calculation based on fuzzy sets (is in)

```
knowledge:
  type: data_driven;
  data:
    patientID := Argument;
    
    if patientID is string then
      patientID := "" || patientID || "";
    endif;

    (physical, fpg, rpg, ogtt)
    := READ (SELECT SCREENING_DM_PHYS, SCREENING_DM_FPG, SCREENING_DM_RPG, SCREENING_DM_OGGTT
                FROM Screening
                WHERE IDPatient = patientID);

    // Fuzzy set definitions
    fa_fpg_opt := fuzzy set (7.7, 1), (7.9, 0);
    fa_fpg_opt := fuzzy set (5.9, 0), (6.3, 1), (6.9, 1), (7.3, 0);
    fa_fpg_opt := fuzzy set (6.0, 1), (6.2, 0);
    fa_fpg_opt := fuzzy set (7.0, 1), (7.2, 0);
    fa_fpg_opt := fuzzy set (7.6, 0), (7.8, 1), (11.0, 2), (11.2, 0);

    if priority: ;;
      evoke: ;;
    logic:
      // Start - Checking for impaired glucose regulation
      // Impaired fasting glycaemia
      if fpg is in fa_fpg_opt and ogtt is in fa_fpg_opt then
        notification := localized 'IFG';
      endif;
      conclude true;
      conclude true;
      // End - Checking for impaired glucose regulation
      ;;
      action:
      return notification:
      ;;
```