Electronic Surveillance of Healthcare-Associated Infections Using HL7's Arden Syntax

Dr. Klaus-Peter Adlassnig

By Dr. Klaus-Peter Adlassnig, CEO and Scientific Head, Medexter Healthcare in Vienna, Austria; and Section for Medical Expert and Knowledge-Based Systems, Center for Medical Statistics, Informatics, and Intelligent Systems, Medical University of Vienna

Arden Syntax is a medical knowledge representation and processing scheme for the development of clinical decision support (CDS) systems that that originated in 1989 at a gathering of several medical informaticists from the USA, the Netherlands, and Sweden at the Arden Homestead Retreat in Orange County, NY, conference estates owned by the Columbia University. The intention was to write computer-based clinical reminders, diagnostic and therapeutic recommendations, and crucial alerts in a clear and readable way and—as one of the main objectives—to make them shareable to others.

Since then, the early versions of Arden Syntax have been updated, extended, and were adopted by standards organizations. The American Society for Testing and Materials (ASTM) first approved the Arden Syntax as standard E-1460-92 in 1992. Ownership was transferred to Health Level Seven (HL7) and the American National Standards Institute (ANSI) in 1999 with the approval of version 2.0 of the standard. The latest release is Arden Syntax version 2.8 which was approved in January 2012; however, HL7's Arden Syntax Work Group is still preparing further improvements of, and extensions to, this representation and programming code.

Arden Syntax is a syntax defining how to arrange input data to be processed, condition and action parts of clinical rules to be written, and how and where to output the computed results. Medical logic modules (MLMs) are the basic representation and processing units in Arden Syntax, and the syntax was designed such that each MLM may contain all the knowledge for at least one single decision. However, MLMs can call each other, be interconnected, even intertwined, and can thus form whole medical knowledge packages (MKPs)[1], consisting of sets of MLMs.

To make the syntax operable, one needs to write—say program in a programming language—an interpreter or compiler for Arden Syntax, and an execution engine to have the MLMs being processed. In addition, an authoring tool containing an editor for writing MLMs—which possibly includes an execution engine for testing them before they become enacted—usually comes with such a suite of Arden Syntax software.

Following current software architectures and providing the Arden Syntax execution engine within a service-oriented architecture makes it possible to offer interoperable CDS systems for a variety of tasks. These tasks all have in common that data sources such as clinical, laboratory, or intensive care information systems or the web "itself" supply the data to be processed—preferably through standardized data communication—and that the MLM-processed results be returned to the connected information systems or be reported by separate web-based applications.

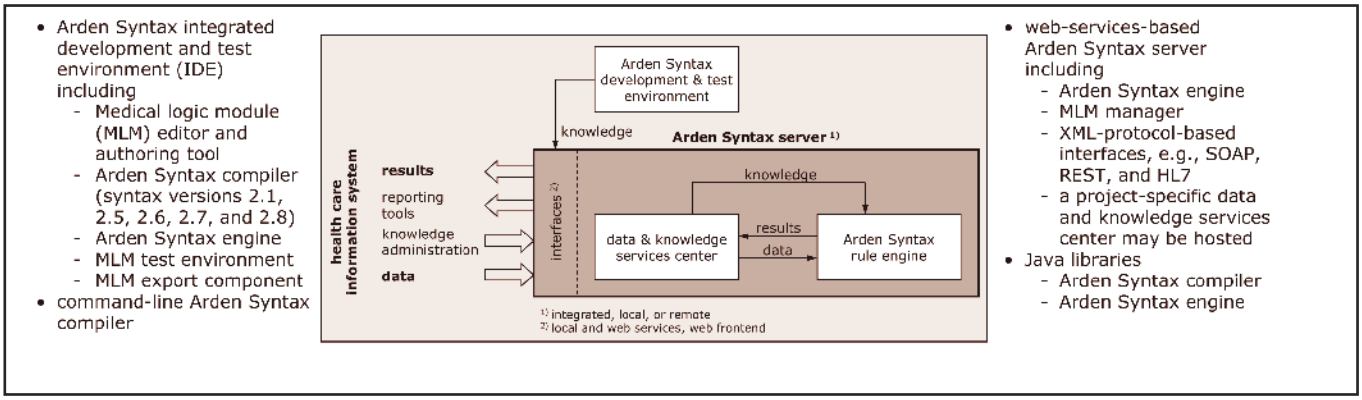

Figure 1: Suite of Arden Syntax software—service-oriented architecture and software components

Figure 1 shows the structure of an Arden-Syntax-based, service-oriented CDS system and lists some of its software components, as it is offered and applied by Medexter Healthcare. This software for Arden Syntax was written, distributed, and has been incorporated into a number of hospitals and some healthcare companies information systems.

One large-scale application is called Moni-ICU and runs as clinical routine application at the Vienna General Hospital, a tertiary care hospital with 2,134 beds and the main teaching hospital of the Medical University of Vienna, Austria. Moni-ICU has been built for electronic, fully-automated surveillance of healthcare-associated infections (HAIs) at the hospital's intensive care units (ICUs) with adult patients. The primary user is the infection control team of the Clinical Department of Hospital Hygiene of the Vienna General Hospital, which receives daily automated updates on its cockpit surveillance screen to see which patient at which ICU ward developed an ICU-associated infection, continued to have one, or recovered from one (See Figure 2). Based on classification criteria for HAIs, as they have been issued by the US Centers for Disease Control (CDC), the European CDC, and German KISS, the published definitions of the various forms of septicemias, pneumonias, urinary tract and central-venous-catheter-associated infections were linguistically decomposed, formally rearranged and structured, and brought into Arden Syntax MLM code.

Processing layers from raw data calculation and interpretation to intermediate and high-level clinical concept evaluation were introduced and a package of hierarchically interwoven MLMs was established (Figure 3). Patients' medical data is measured, observed and automatically transferred from the intensive care medical information systems and the microbiology laboratory. It is then put through a step-by-step pipeline of aggregation, interpretation, and evaluation that is eventually used to draw conclusions about whether one or more of the included infection criteria are fulfilled, fulfilled to a certain degree, or not fulfilled. Most of the encoded clinical entities are modeled as fuzzy sets, and fuzzy logic is used to perform the subsequent inference steps. Figure 3 shows a graphical depiction of the processing layers in Moni-ICU.

At present, this Arden Syntax application is used by 12 ICUs with a total of 96 beds and the microbiology department provide about 15-18,000 data items every day. For each of the 96 patients, an Arden Syntax knowledge package containing 74 MLMs (with emulated clinical fuzzy set definitions and fuzzy logic processing operators) is automatically invoked, and both intermediate medical concepts and final infection results are computed, stored, and prepared for viewing on screen or for reporting.

A study evaluating the effectiveness has shown an excellent conformance of Moni-ICU with an established clinical reference standard as well as Moni-ICU's superiority in

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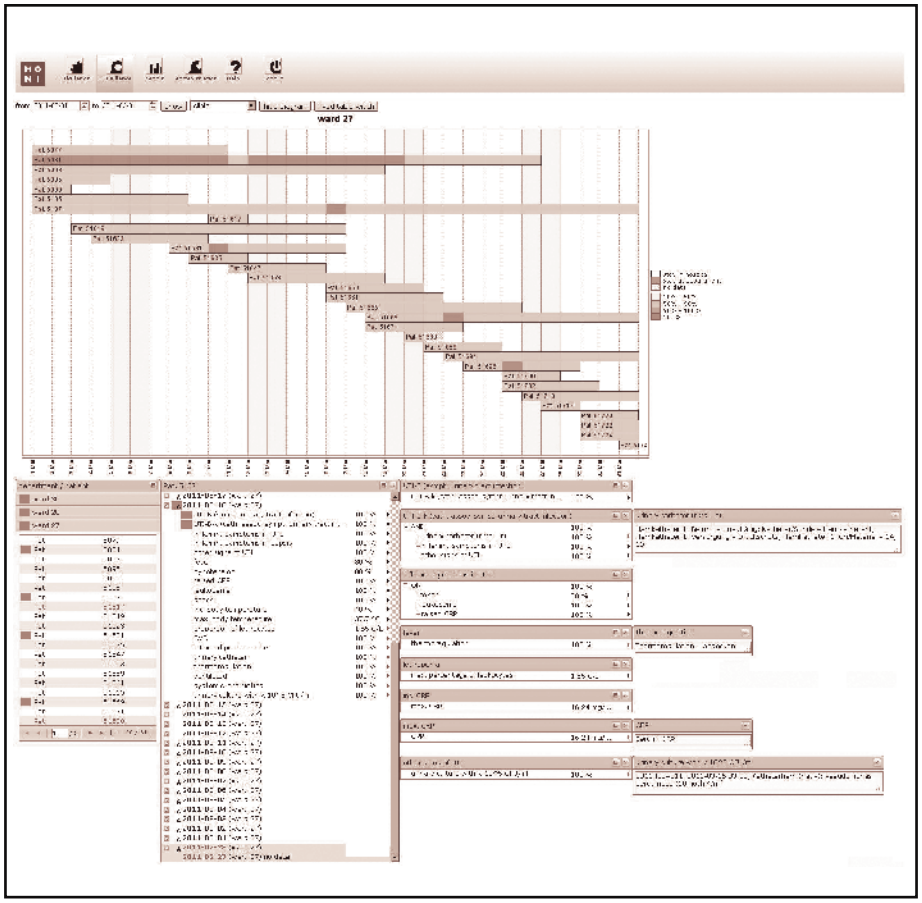

Figure 2: Screenshot of Moni-ICU showing daily results (lower half, middle part) including detailed explanations (lower half, right part) and patients' infection period over time (upper half)

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minimizing time demands on the infection control team with respect to electronically supported versus sole human surveillance [2].

The next steps include extending Moni-ICU to neonatal care (Moni-NICU), forming standardized interfaces to medical information systems applying the HL7 messaging standards, defining and adopting a genuine Fuzzy Arden Syntax (presumably Arden Syntax version 2.9), and adding several automated reporting schemes for HAIs as requested by legal requirements in Austria, Germany, and the US.

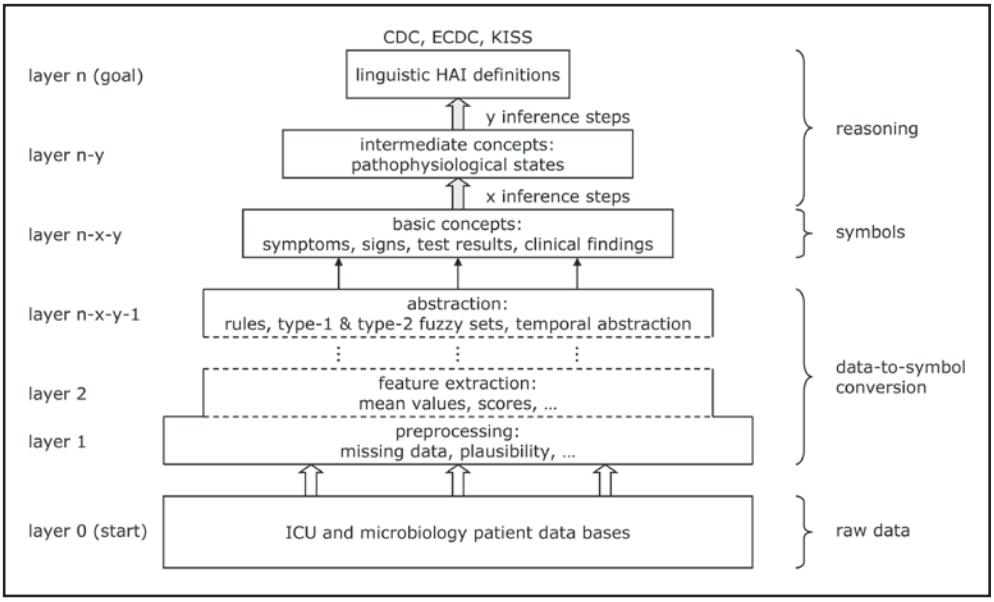

Figure 3: Processing layers from raw data to high-level clinical concept evaluation using Arden Syntax

[1] Adlassnig, K.-P. and Rappelsberger, A. (2008) Medical Knowledge Packages and their Integration into Health-Care Information Systems and the World Wide Web. In Andersen S.K., Klein, G.O., Schulz, S., Aarts, J., and Mazzoleni, M.C. (Eds.) eHealth Beyond the Horizon–Get IT There. In Proceedings of the 21st International Congress of the European Federation for Medical Informatics (MIE 2008), IOS Press, Amsterdam, 121–126.

[2] Blacky, A., Mandl, H., Adlassnig, K.-P., and Koller, W. (2011) Fully Automated Surveillance of Healthcare-Associated Infections with MONI-ICU – A Breakthrough in Clinical Infection Surveillance. Applied Clinical Informatics 2(3), 365–372.

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