CDSS

- CDS systems may be described in terms of five right things that they do: they "provide the right information, to the right person, in the right format, through the right channel, at the right point in workflow to improve health and health care decisions and outcomes"

- Systems that provide CDS come in three basic varieties:

1. They may use information about the current clinical context to retrieve highly relevant online documents, as with so-called " infobuttons "
2. they may provide patient-specific, situation-specific alerts reminders, physician order sets, or other recommendations for direct action
3. they may organize and present information in a way that facilitates problem solving and decision making, as in dashboards , graphical displays, documentation templates, structured reports, and order sets.

22.1 The Nature of Clinical Decision-Making

- As we develop databases that can identify patients with specific diseases, with risks of complications, or in need of specific interventions such as screening tests or immunizations so-called **population management** can be used to provide a form of decision support for groups of patients.
- The requirements for excellent decision-making fall into three principal categories: (1) accurate data, (2) pertinent knowledge, and (3) appropriate problem-solving skills.
- It is important to know when additional data will confuse rather than clarify and when it is imperative to use tools that permit data to be summarized for easier cognitive management. Operating rooms and intensive-care units are classic settings in which this problem arises; patients are monitored extensively, numerous data are collected, and decisions often have to be made on an emergent basis.

22.2 Motivation for Computer-Based CDS

Computer-based CDS has taken on increasing urgency for three reasons: (1) increasing challenges related to knowledge and information management in clinical practice, (2) the pressure to adopt and meaningfully use electronic medical records, and (3) the goal of delivering increasing personalized health care services – tailored to the patient's preferences for care and to his or her individual genome.

22.2.2 EHR Adoption and Meaningful Use

The **American Recovery and Reinvestment Act (ARRA), and the HITECH** regulations within it, created incentives for the widespread adoption of health information technologies.

22.3 methods of CDS

- CDS systems (1) may use information about the current clinical context to retrieve online documents; or (2) may provide patient-specific, situation specific alerts, reminders, physician order sets, (3) may organize information in ways that facilitate decision making and action. Category (2) largely consists of the various computer–based approaches ("classic" CDS systems) that were developed in biomedical informatics.Such systems provide custom tailored assessments on sets of patient-specific data.

- They may follow simple logics (such as algorithms), they may be based on decision theory and cost–benefit analysis, or they may use probabilistic approaches only as an adjunct to symbolic problem solving.
- Example of a diagnostic assistants (DXplain Barnett)
- Example of a system that summarizes the patient record according to relevance (Shahar and Musen).
- Other systems provide therapy advice rather than diagnostic assistance (Musen).
- What are the reasons that prevented the wide use of CDS?

1. Scientific limitations
2. Logistical limitations (program developers had difficulty convincing doctors to use these systems that they were not used to)
3. Lack of availability of needed data

- **THREE CDS SYSTEMS YOU HAVE TO KNOW!**

1. **HELP:**delivers **inpatient alerts** when abnormalities in the patient records were noted

- HELP is event-driven(the event is the abnormality)
- It used the **Arden Syntax (a programming language that relates a situation to an action)**
- **In the arden syntax,each decision or rule is called MEDICAL LOGIC module-(which is an event condition action rule (ECA rule)**
- **Reminders have a trigger which is TIME!**
- the integration of CDS with EHR functionality in the HELP system was an important move away from the idea of standalone "consultation systems," such as MYCIN,

2. **MYCIN:program that helps in the selection of antibiotics--->used a rule based consultation system to represent knowledge.**

- What is a production rule? A conditional statement that relates observations to inferences that can be drawn.
- Mycin's power: is from the production rule
- Mycin used (backwards chaining): looks backward to check if the right or left side of rule is true.(إما تشوف لو الشرط صحيح أو تشوف لو جواب الشرط صحيح باستخدام قاعدة البيانات)
- **Nowadays ALL rule based systems use forward chaining.**
- By studying how MYCIN worked ,this helped developers with a techniques called **KNOWLEDGE ACQUISITION.**

3. **De Dombal's System for diagnosis of abdominal pain--->used Bayes' theorum ,and was correct in diagnosis 91.8% of the time (better than physician)**

(these three systems were not clinically relevant ,but they are important because they inspired modern CDS systems)

22.4 Principles of CDS System Design:

Modern CDS systems typically achieve their results using:

- Bayesian reasoning.
- production rules.

- MLMs.**"medical logic module"**
- knowledge-based groupings of physician orders,referred to as "**order sets**," and other templates.
- or by the use of prediction associations derived by mining and analysis of EHR data (or some combination of these approaches).

Contemporary systems may acquire the data on which they base their recommendations:

- Interactively from users.
- OR directly from a health information system (or some combination of these approaches).

22.4.1 Acquisition and Validation of Patient Data

- **A primary obstacle** is that we lack standardized ways of expressing most clinical situations in a form that computers can interpret.
- Still, there is **NO** *controlled terminology* that can capture all the nuances of a patient's history of present illness or findings on physical examination.
- There is **NO** *coding system* that can reflect all the details of physicians' or nurses' progress notes.
- The prose of progress notes, consultation notes, operation reports, discharge summaries, and other documents contains an enormous amount of information that **NEVER** makes it to the coded part of the EHR.

Variety of techniques for data acquisition, ranging from:

- Work in **natural language processing** has made major advances in recent years, making it increasingly possible **to mine the textual notes of EHRs** to identify information that might bear on the CDS process.

22.4.2 Decision-Making Process:

- When building CDS systems, most of the work is concentrated on the **development of the reasoning system** and the specification of the knowledge on which that reasoning system operates.

22.4.2.1 Infobuttons:

- **Infobuttons**: The simplest, and perhaps **most common,** form of **CDS** uses contextual information from an EHR to perform information retrieval from a database of information about online documents.

Function:

- Clicking on an infobutton causes the clinical information system to perform a query on the database, providing the user with one or more immediately accessible resources.

Example:

- Clicking on an infobutton next to a drug, allow the user to access information about customary *dosing*, *side effects*, or *alternative medications.*
- **infobutton manager***:* mediates the queries between the clinical information system and the available information resources. Need to anticipate how the clinical context might tailor the specific query performed by any given infobutton.

- Infobutton managers therefore require **sophisticated query capabilities**, but they do **NOT** need to reason from a clinical situation to a particular recommendation.
- **The sophistication** of the required technique is a function of the kind of inference that is necessary to render a result for the user.
- **HL7** has created a standard for "**context-aware knowledge retrieval**," leading to infobutton managers that have been adopted by many commercial EHR vendors.
- Current research concentrates on the development of a **Librarian Tailoring Infobutton Environment (LITE)** that promises to aid the authoring of infobutton queries via "**wizards**" and other user interface conveniences.
- Infobuttons retrieve relevant information for a user, but they do **NOT** explicitly address particular decisions that the user needs to make.

22.4.2.2 Branching Logic

An exception/ a computer program deployed in Boston at what was then the Beth Israel Hospital: It used detailed **algorithmic logic** to provide advice regarding the diagnosis and management of acid–base and electrolyte disorders.

- The **algorithmic representation** of clinical procedures is extremely useful for clinicians when they think about the representation of preferred clinical **workflows**.
- **Heterogeneous knowledge representations** needed to drive sophisticated CDSS systems.

22.4.2.3 Probabilistic Systems:

- Large numbers of **Bayesian diagnosis programs** have been developed in the intervening years, many of which have been shown to be **accurate in selecting among competing explanations of a patient's disease state.**
- In *England*, who adopted a **naïve Bayesian model** that assumed that there are **NO** conditional dependencies among findings (i.e., a model that could make the inappropriate assumption that the presence of a finding such as fever never affects the likelihood of the presence of a finding such as chills)
- Although a **naïve Bayesian model** may have **limitations** in accurately modeling a diagnostic problem, a **major strength** of this approach is **computational efficiency.**
- This **sequential Bayes** approach was explored for the diagnosis of **congenital heart disease** and has been used in many CDS systems since.

22.4.2.4 Rule-Based Approaches:

- The knowledge in a knowledge-based system may include ***probabilistic relations***, such as:

1. Between symptoms and underlying diseases.
2. Relations are augmented by additional qualitative relations, such as causality and temporal relations.

- When a knowledge-based system is **encoded using production rules**, it is referred to as a **rule-based system.**

Importance?

- Rule-based systems provide the dominant mechanism for developers to build CDS capabilities into modern information systems.
- Rules provide an extremely convenient means to encode the necessary knowledge.

Example:

- From CDS systems that interpret ECG signals to those that recommend guideline-based therapy.
- Rule-based systems require a **formal language** for encoding the rules, plus an interpreter (Called: **Inference engine**)
- **MYCIN** required the developer to encode rules in a predefined manner using **Lisp Programming Language.**
- Although the developers of MYCIN had to construct their own syntax for encoding rules and had to program their own inference engine to evaluate the rules, there now are many open-source and proprietary **"rule engines"** that provide **custom-tailored editors for writing rules** and inference engines that can execute the rules at runtime.

- **Arden Syntax specifies** that the individual database queries needed to determine the values of the variables should appear within the "**curly braces**" of variable definitions in the portion of the MLM known as the **"data slot".**

How?

- The standard was created with the idea that the shared syntax would allow an MLM written in an **idiosyncratic representation system** (for example, the one adopted by HELP) to be translated into a canonical format for execution in other information systems.

What is missing from the standard?

- Is any notion of **the semantics** of the data on which the MLMs "medical logic module" operate.
- **EHR information models** and the way in which elements are coded *differ* from system to system. Thus, all **system-specific aspects of MLM integration** need to be provided within the *curly braces.*

What is the problem in MLMs?

- The problem is compounded because there may be assumptions regarding the semantics of the variables themselves that may not be obvi-
ous to the local implementer:

For example:

1. If the MLM refers to serum potassium, should the logic be executed if the original specimen was grossly hemolyzed?
2. If a serum potassium value is not available in the database, but there is a value for a whole-blood potassium, should the MLM be executed using that value instead?
3. If there is no serum potassium value available for today, but there is one from last night, should the logic execute using the most recent value?

The answer:

- MLMs **cannot** simply be dropped from one system into another and be shared effortlessly; rather, considerable thought, analysis, and computer skill needs to go into writing the appropriate database queries that go within the curly braces to make MLMs operational.
- This obstacle to sharing MLMs that are written in the Arden Syntax is known, appropriately and whimsically, as **"the curly braces problem".**
- The lack of standards for what goes between Arden's curly braces has been a **major impediment** both to the **sharing of MLMs** and to the **creation of reference** libraries of clinical decision rules.
- **HL7** recognized this difficulty early on, and developed an abstract expression language for specifying database queries known as **"GELLO"**
- ***MLMs written in terms of GELLO queries on the virtual EHR can be translated programmatically into actual queries on patient data as available at a local institution.***

- **HL7** approved a **draft standard for trial use (DSTU) for a virtual EHR (known for historical reasons as a virtual medical record , or vMR)**
- HL7 standards, it is **unlikely** that the curly braces problem will be going away anytime soon.

For example:

- **In the case of Arden Syntax**, developers write rules to deal with **one** clinical problem at a time.
- There may be one MLM to deal with the problem of administering a drug like penicillin to a patient with a history of penicillin allergy.
- Another MLM may report that a patient has a dangerously low serum potassium value.
- **Unlike the rules in MYCIN**, MLMs are generally **not intended to interact with one another** or to be chained together to generate complex inferences. *MLMs may be coerced to chain* ***together*** *when one MLM posts to the patient database a value that can trigger another MLM.*

Disadvantages:

Same disadvantages that came to light with chaining rule-based systems such as **MYCIN**:

1. When the rule base grows to a **large size**, interactions among rules may have unanticipated side effects.
2. when rules are **added to or deleted from** a previously debugged knowledge base, there may be unexpected system behaviors.

For MLMs to work well in practice:

The rules need to be tailored to the particular clinical environment—triggered by appropriate:

1. Workflow events.
2. Interacting with particular kinds of participants.
3. Customizing logic to account for various business.(To customize an MLM to account for such considerations requires that it become less portable.)
4. Workflow processes.
5. Notifying the user in setting-specific ways.

- Much of the effort required **to introduce CDS systems** into the healthcare enterprise involves precisely such **adaptations**.
- **To accelerate portability,** MLM developers must seek a balance between a generic specification of logic that is widely agreed upon, and site-specific customizations that will facilitate the use of that logic.
- **Achieving the right balance will always remain an elusive target.**

22.4.2.5 Ontology-Driven CDS Systems

- The ATHENA-CDS system exemplifies this component-oriented approach.

- Because the standard documents that define clinical practice guidelines can be long and complicated, it is extremely helpful for the computer to focus the clinician's attention on precisely which interventions should be considered to guarantee that the patient's care is consonant with the medical evidence captured by a given guideline .

- ATHENA-CDS was engineered using an approach that separates out **static knowledge** about the clinical application area from knowledge about **problem solving**. The developers began by creating an **ontology** of clinical guidelines in general.

- An **ontology** is like a controlled terminology that includes not only an enumeration of the important entities in some application area, but also in machine-processable form the relationships among those entities and, possibly, constraints on those entities. Thus, an ontology contains taxonomic relationships that indicate, for example, that *cholesterol* is a kind of *lipid* or that a *serum potassium* is a kind of *laboratory test*. An ontology may also contain partitive relationships that indicate, for example, that a *systolic blood pressure measurement* is part of a *blood pressure measurement*.

- To construct ATHENA-CDS, it was necessary first to define an ontology of clinical practice guidelines. The guideline ontology makes it clear that all guidelines must include *eligibility criteria* that indicate which patients should be treated in accordance with the guideline, a *clinical algorithm* that specifies the sequence of treatments recommended by the guideline, and *guideline drugs* that represent all the medications that patients.

- Because the **guideline ontology is general**, it does not contain information about any *particular* clinical algorithm, any *particular* eligibility.

- The ontology merely states that all guidelines for management of chronic diseases have such characteristics.

- Developers of ATHENA-CDS used the **Protégé ontology-development system** to create the ontology of clinical practice guidelines .

- Developers created a knowledge base for management of hypertension, congestive heart failure ,diabetes, hyperlipidemia, and chronic kidney disease were created in a similar manner.

- The ATHENA-CDS guideline ontology can be viewed as a **hierarchy of classes** in an object oriented language. Each object defines an entity in the ontology (e.g., clinical algorithm, guideline drugs). To create a knowledge base (such as the one for hypertension management), the classes in the object hierarchy are instantiated to define the particular *clinical algorithm* .

- Indeed, editing and maintaining the ATHENA-CDS knowledge bases has been something that trained clinicians generally have done on their own without much assistance from workers in informatics.

- In the approach demonstrated by ATHENA- CDS, software engineers create specialized computer programs that encode the procedures needed to perform different tasks using the knowledge base. For example, in ATHENA- CDS, a problem-solving program uses a guideline knowledge base (for example, the knowledge base that encodes the VA/DOD/JNC guideline for management of hypertension) in conjunction with data that the program queries from the VistA EHR.The approach separates the static knowledge base from problem solvers that operate on that knowledge base. Thus, a different problem-solving program could use the knowledge base and available EHR data to determine whether a patient is eligible for treatment in accordance with the guideline.

- Another problem-solving program could perform quality assurance to assess whether past patients have been treated in accordance with the guideline, when appropriate .

-The **ontology-driven approach** makes it possible to start with a particular ontology to create multiple knowledge bases, each one instantiating the ontology to specify the knowledge required for particular guidelines. Similarly, the different knowledge bases can be mapped to different problem-solving programs, such that each problem solver automates a different task associated with guideline-based care .The ability to "mix and match" knowledge bases and problem solvers offers considerable flexibility, and enables developers to reuse elements of previous solutions to address new CDS problems that require different domain knowledge or different problem-solving procedures.

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