Decision support

- It has long been recognized that computers have the potential to improve decision support in health care
- Early approaches focused on application of artificial intelligence and expert systems to improve medical diagnosis
- But computer-aided diagnosis proved difficult and it became apparent computers could better be used in more focused decision support capacities to improve quality and reduce errors
**Why look back?**

- Diagnostic decision support was a major focus of the field in the early days, circa 1970s and 1980s
- It laid the intellectual groundwork for techniques used in modern decision support systems and shift of focus to therapeutic decision support
- With the availability of data in the modern electronic health record (EHR), the older approaches may yet be useful in the future

**Let’s define some terms**

- Artificial intelligence (AI) – the area of computer science concerned with building computer programs that exhibit characteristics associated with human intelligence
- Expert system (ES) – a computer program that mimics human expertise
- Decision support system (DSS) – also mimics human expertise but acts in more of a supportive than independent role
  - Diagnostic decision support – focused on aiding in diagnosis of patients
  - Therapeutic decision support – focused on aiding in treatment of patients
Early efforts arose out of attempts to “quantify” medical diagnosis

- Ledley and Lusted (1959, 1960) proposed mathematical model for diagnosis
  - Clinical findings based on set theory and symbolic logic, with diagnosis made using probabilities
- Warner (1961) developed a mathematical model for diagnosing congenital heart disease
  - Approach used contingency table with diagnoses as rows and symptoms as columns
  - System predicted diagnosis with the highest conditional probability given a set of symptoms

Approaches to diagnostic ESs

- Functions of systems tightly linked to methods for knowledge representation
- Four general approaches
  - Clinical algorithms
  - Bayesian statistics
  - Production rules
  - Scoring and heuristics
- Current approaches taken advantage of modern EHRs and other advances
Clinical algorithms

• Follow path through “flow chart”
• Elements in chart are nodes
  – Data is gathered at information nodes
  – Decisions are made at decision nodes

Clinical algorithms (cont.)

• Benefits
  – Knowledge is explicit
  – Knowledge is easy to encode

• Limitations
  – No accounting for prior results
  – Inability to pursue new etiologies, treatments, etc.
  – New knowledge difficult to generate

• Forerunner of modern clinical practice guidelines
Bayesian statistics

• Based on Bayes’ theorem, which calculates probability based on prior probability and new information

• Assumptions of Bayes’ theorem
  – Conditional independence of findings – no relationship between different findings for a given disease
  – Mutual exclusivity of conditions – more than one disease does not occur

Bayes’ Theorem generalized form

• Probability of disease $i$ in the face of evidence $E$, out of a set of possible $j$ diseases is:

$$P(D_i | E) = \frac{P(D_i) P(E|D_i)}{\Sigma P(D_j) P(E|D_j)}$$

• Translation of formula: the probability of a disease given one or more findings can be calculated from
  – The prior probability of the disease
  – The probability of findings occurring in the disease
Implementation and limitations of Bayesian approach

• Leeds Abdominal Pain System (de Dombal, 1975)
  – Most successful implementation, used in diagnosis of acute abdominal pain
  – Performed better than physicians – accuracy 92% vs. clinicians 65-80%, better in 6 of 7 disease categories
  – But difficult to use and not transportable to other locations (Berg, 1997)

• Limitations of Bayesian statistics
  – Findings in a disease are usually not conditionally independent
  – Diseases themselves may not be mutually exclusive
  – When multiple findings important in diagnosis, reaches high computational complexity quickly

Production rules

• Knowledge encoded as IF-THEN rules
• System combines evidence from different rules to arrive at a diagnosis
• Two types of rule-based ESs:
  – Backward chaining – System pursues goal and ask questions to reach goal
  – Forward chaining – Similar to clinical algorithms, with computer following proscribed path to reach answer
• Generic rule: IF test-X shows result-Y THEN conclude Z (with certainty p)
The first rule-based ES in medicine: MYCIN

• PhD dissertation of Shortliffe (1975) and one of the first applications in medical informatics

• Major features
  – Diagnosed the infectious diseases, meningitis and bacteremia
  – Used backward chaining approach
  – Asked questions (relentlessly!) in an attempt to reach diagnosis

• Evaluation of MYCIN (Yu, 1979)
  – 10 cases of meningitis assessed by physician experts and MYCIN; output judged by other physician experts
  – Recommendations of experienced physicians judged acceptable 43-63% of the time, compared with 65% of the time for MYCIN
  – In no cases did MYCIN fail to recommend an antibiotic that would cover the infection (even if it was not optimal choice)

Limitations of rule-based systems

• Depth-first searching could lead to focus in wrong area

• Rule bases were large and difficult to maintain
  – MYCIN had 400 rules covering two types of bacterial infection
  – Approach worked better in constrained domains, such as pulmonary function test interpretation

• Systems were slow and time-consuming to use
  – Rule-based goal seeking could take long time
  – System also developed prior to era of modern computers and graphical user interfaces