

CSC490/2600

Artificial intelligence in clinical medicine Frank Rudzicz Fall 2016 University of Toronto

Lecture 1

Science fiction, science fact







csc490/2600 — lecture 1

Science fiction, science fact











What do the experts say?

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NEWS Employment outlook and skills stability, by industry Home Video World US & Car Technology Will a robot take 100 Negative outlook, Positive outlook, skills stable skills stable () 11 September 2015 Technology 90 80 Type your Media, Entertainment and Information Energy Consumer be automa Healthcare AVERAGE Professional Services 70 About 35% 2015-2020, % Skills stability Information and Communication Technolog 20 years, a Mohilit 60 Basic and Infrastructure Medical p Financial Services & Investors 50 Likelihood of 40 It's quite un 30 How this compa 20 100% Negative outlook, Positive outlook, 75% 10 skills disrupted skills disrupted 50% 0 25% -1.0-0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 Most likelv Expected change in employment, 2015-2020, %

"Technology will replace 80% of what doctors do"

- Vinod Khosla

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Frey, C.B. and Osborne, M.A. (2013) The Future of Employment: How Susceptible Are Jobs to Computerization?" Oxford University Martin School. World Economic Forum (2016) The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Executive summary

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Specialty *n*. A specific sub discipline of medicine

What does a doctor do?

- Anaesthetist
- Family doctor
- General surgery
- Internist
- Neurologist
- Paediatrician
- Psychiatrist
- Radiologist
- ••••





Specialty *n*. A specific sub discipline of medicine

What does a clinician do?

- Mental health counsellor
- Nurse practitioner
- Occupational therapist
- Optometrist
- Paramedic
- Physical therapist
- Psychologist
- Speech-Language pathologist
- ••••





Health Professionals per 100,000 Population⁺

| | Total | Physicia | ins - 2000 | Registered | Chiropractors | Dental Hygienists | Dentists | Dietitians | LPNs | Medical Laboratory Technologists | Medical Radiation Technologists |
|----|------------|----------|-------------|-------------|---------------|----------------------|----------|------------|------|--|---------------------------------------|
| | Physicians | GP/FP | Specialists | Nurses 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| NF | 172 | 106 | 66 | 1,002 | 6 | 13 | 30 | 23 | 533 | 59 | 49 |
| PE | 128 | 75 | 52 | 903 | 5 | 31 | 43 | 36 | 448 | 75 | 49 |
| NS | 201 | 101 | 100 | 923 | 7 | 44 | 48 | 40 | 329 | 79 | 53 |
| NB | 152 | 90 | 63 | 974 | 6 | 33 | 35 | 33 | 294 | 81 | 62 |
| QC | 214 | 106 | 108 | 796 | 13 | 49 | 54 | 26 | 210 | 37 | 50 |
| ON | 180 | 85 | 95 | 697 | 23 | 56 | 60 | 19 | 225 | 60 | 45 |
| MB | 181 | 92 | 89 | 875 | 18 | 49 | 49 | 23 | 202 | 83 | 52 |
| SK | 154 | 91 | 62 | 835 | 16 | 27 | 34 | 22 | 151 | 91 | 43 |
| AB | 166 | 86 | 80 | 736 | 23 | 43 | 54 | 20 | 136 | 61 | 48 |
| BC | 195 | 106 | 88 | 681 | 18 | 44 | 65 | 21** | 108* | 59 | 42 |
| ΥT | 136 | 116 | 20 | 779 | 30 | 50 | 60 | | | 53 | |
| NT | 112 | 69 | 43 | 1,027 | | 20 | 71 |] | 157 | 41 | |
| NU | 25 | 21 | 4 | 333 | | 30 | | | 157 | 41 | |



| | Midwives 2000 | Occupational Therapists 2000 | Optometrists 2000 | Pharmacists 2000 | Physiotherapis 2000 | Registered ts Psychiatric Nurses 2000 | Respiratory Therapists 1998 | |
|-----------|------------------|------------------------------------|----------------------|---------------------|------------------------|---|-----------------------------------|--|
| NF | | 25 | 6 | 96 | 37 | - | 14 | |
| PE | | 24 | 8 | 86 | 34 | | 12 | |
| NS | | 26 | 7 | 100 | 45 | | 24 | |
| NB | | 27 | 12 | 75 | 53 | | 26 | |
| QC | 1 | 35 | 16 | 77 | 43 | | 29 | |
| ON | 2 | 29 | 10 | 72 | 43 | | 15 | |
| MB | 2 | 37 | 8 | 78 | 46 | 89 | 17 | |
| SK | | 22 | 11 | 109 | 52 | 103 | 11 | |
| AB | 1 | 32 | 10 | 96 | 54 | 38 | 28 | |
| BC | 1 | 30 | 8 | 80 | 57 | 54 | 13 | |
| YT | | 20 | 10 | 86 | | | | |
| NT NII | | 10 | | 43 | | | 6 | |

Notes: † Data are preliminary as of November 2001 and are subject to change. Rates per 100,000 population. With the exception of physician and registered nurse data, personnel per 100,000 ratios for the Northwest Territories include Nunavut Territory data.

- * Data for 2000 British Columbia LPNs are estimates.
- **B.C dietitions include dietitions and nutritionists
- " Not Available.

Note: due to updated population estimates frequencies may differ slightly from past publications.

Source: Southam Medical Database, CIHI. Health Personnel Database, CIHI. Registered Nurses Database, CIHI.

How Physicians Spend Their Work Time

For more than a decade, the Canadian Medical Association has asked physicians about how they spend their work time. The graph below shows the results—the average number of hours worked per week by full and part-time Canadian physicians between 1982 and 2001, excluding time spent on-call. Annual averages range from a low of just under 47 hours in 1993 to a high of 54 hours in 1999. Most of this time was spent on direct patient care. Other activities included indirect patient care (e.g. other phone calls or charting), administration, research, teaching, continuing medical education (CME), or other activities. Figures prior to 1993 are based on census surveys of all physicians (including family doctors and specialists) in Canada; later figures come from sample surveys.



Source: Physician Resource Questionnaire, Canadian Medical Association

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Decisions under uncertainty

- Humans, like our computer cousins, routinely have to make decisions based on imperfect input...
 - Family history
 - Oral reports from patients
 - Lab results
- * ... and rely on **imperfect knowledge**.
 - Changes to practice
 - Basic retrieval of information









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Toronto Notes

Decision criteria

- Maximin: "best worst" payoff < minimum outcome</p>
- Maximax: "best best" payoff <- best possible</p>
- Laplace: "best average" payoff
- Minimax regret (opportunity loss): "best worst" regret minimizes difference between realized payoff and best payoff for each future condition



To err is human

- **# Humans** (and other primates) are notoriously **bad** with **information**.
 - Patients often misread or miscommunicate their own symptoms.
 - Nearly half of American adults have difficulty understanding and acting upon health information (IOM, 2004).
 - Faulty memory; skill obsolescence; cognitive biases;
 cognitive/time limitations; recency biases; other human biases.
 - Diagnoses correlate with advertising and media exposure.



- Winters et al. (2012) showed that ~40,500 patients die in ICU, in the USA, each year due to misdiagnosis.
 - Non-fatal diagnostic errors cost up to \$300,000 per malpractice claim.

http://www.nap.edu/openbook.php?record_id=10883&page=1 Winters *et al.* (2012) Diagnostic errors in the intensive care unit: a systematic review of autopsy studies. *BMJ Qual Saf* 2012;**21**:894-902



To err is human

- * Graber et al. (2005) studied 100 cases of **diagnostic error** involving internists.
 - System-related factors (e.g., poor processes, team problems, miscommunication) contributed to 65% of cases;
 - Cognitive factors contributed to 74% of cases.
 - Most common cause: 'premature closure'.



- Eddy (1990) showed surgeons descriptions of surgical problems. Should the patient have surgery?
 - 50% said Yes, 50% said No.
 - 40% gave conflicting answers upon retesting.

Graber et al. (2005) Diagnostic Error in Internal Medicine. *Arch Intern Med.*, **165**(13):1493-1499 Eddy (1990) The Challenge. *JAMA*, **263**(2):287-290. http://jama.jamanetwork.com/article.aspx?articleid=380215



To compute is divine

- Bennett and Hauser (2013) compared patient outcomes between doctors and sequential decision-making algorithms using 500 randomly selected patients.
 - Estimated Al cost: \$189; Human cost: \$497.
 - Outcomes up to 50% better using AI.

Enlitic showed lung CT scans to their **deep learning system** and to four top **human radiologists**, to diagnose cancer.

Humans: FN 7%; FP 66%. AI: FN 0%; FP 47%.

Bennett and Hauser (2013) Artificial intelligence framework for simulating clinical decision-making: a Markov decision process approach. Artif Intell Med. 57(1):9-19



Example of success



A Profound Example of Digital Health Getting it So Right (mygihealth.io) Reis, B. Y., Kohane, I. S., & Mandl, K. D. (2009). Longitudinal histories as predictors of future diagnoses of domestic abuse: modelling study. *BMJ (Clinical Research Ed.)*, **339**, b3677. <u>http://doi.org/10.1136/bmj.b3677</u> csc490/2600 — lecture 1 What to expect in this course

The road ahead

Week 1: Healthcare, EMRs, context
Week 2: Language
Week 2.5: Images/video
Week 3: Machine learning and human-computer interaction
Weeks 4-9: PROJECTS!
Week 10: bioethics/implementation

Weeks 11-12: Student presentations





Not on the menu



Surgical robotics



Robots of any kind, really



Not on the menu



Computational biology



Project structure

- Teams of 2-4 students
- Proposals (0.5-1 page) due 21 September
 - Each week starts with group updates hereafter
- Literature review (3-5 pages) due 5 October
- Data & Methodology (3-5 pages) due 19 October
- Preliminary results (1-2 pages) due 2 November
- Student presentations during 21-30 November
- Final reports due 9 December



Evaluation

- Two quizzes during class time, done individually: 5% each
- Participation (i.e., showing up during workshop weeks): 5%

Project: 85%

- Oral presentation: 10%
- **Report**: 90%
 - Data analytics: 15%
 - Code: 15%
 - Experiments/analysis: 30%
 - Literature review: 15%
 - Technical quality: 15%
 - Overall presentation: 10%

Stand up: Every Monday morning, someone from your team will tell everyone:

1) What you've accomplished last week or What challenges you've had

2) What you'll work on next

Your project

Where to make impact?











Spending



National Health Expenditure Trends, Canadian Institute for Health Information, 2010

Department of Health and Human Services, 2011



Health and social service institutions revenue and expenditures, by province and territory (Quebec, Ontario, Manitoba, Saskatchewan)

| | 2009 | | | | |
|--|------------|------------|--------------|--------------------------|--|
| | Canada | Que. | Ont. | Man. | |
| | | : | \$ thousands | | |
| Total revenue | 80,103,978 | 19,735,747 | 26,937,123 | 3,283,411 | |
| Own source revenue | 12,107,664 | 2,306,378 | 5,207,403 | 296,715 | |
| Sales of goods and services | 10,124,989 | 2,128,615 | 4,085,143 | 278,113 | |
| Investment income | 208,214 | 27,895 | 111,664 | 3,257 | |
| Other own source revenue | 1,774,461 | 149,868 | 1,010,596 | 15,346 | |
| Transfers from other levels of government | 67,996,314 | 17,429,369 | 21,729,720 | 2 <mark>,</mark> 986,695 | |
| Federal government | 7,361 | 2,399 | 507 | | |
| Provincial governments | 67,686,684 | 17,426,970 | 21,628,816 | 2,959,046 | |
| Local governments | 302,269 | | 100,396 | 27,649 | |
| Other health and social services | | | | | |
| otal expenditures | 80,826,966 | 19,703,929 | 27,744,375 | 3,363,120 | |
| lealth | 71,435,800 | 15,990,403 | 26,052,730 | 3,021,344 | |
| Hospital care | 37,336,376 | 8,351,064 | 15,472,861 | 1,290,216 | |
| Medical care | 16,558,004 | 3,164,202 | 5,323,829 | 725,733 | |
| Preventive care | 1,636,130 | 688,918 | 660,658 | | |
| Other health services | 15,905,290 | 3,786,219 | 4,595,383 | 1,005,395 | |
| Social services | 9,112,216 | 3,483,525 | 1,658,292 | 338,930 | |
| Social assistance | 3,299 | | 484 | •• | |
| Other social services | 9,108,917 | 3,483,525 | 1,657,808 | 338,930 | |
| Debt charges | 278,949 | 230,002 | 33,352 | 2,846 | |
| Protection of persons and property | | | | | |
| Housing | | | | •• | |
| Surplus or deficit | -722,988 | 31,818 | -807,252 | -79,709 | |

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The future of care delivery

When Care is Delivered



Retina Selfie – Retina selfimaging allows patients to monitor for diseases such as multiple sclerosis and detect early warning signs Sample Use Cases

Where Care is Delivered



Healogram – Mobile platform that helps providers remotely monitor patients post-surgical

procedure

notely ents



iDAvatars – 2D avatar, Sophie, uses artificial intelligence and natural language processing to remotely monitor patients

By whom Care is

Delivered













Case study: BIDMC and HMS





The future of the patient

| | - Sample Use Cases | |
|---|--|--|
| Self service | New ways to engage | The quantified self |
| Tyto Care – handheld device that patients can use to self- | Deloitte Cognitive Engagement – designed to boost patient involvement in care and expand the type of alerts and interactivity offered online | Ginger.io – aggregates cellphone data to monitor patient mental health & alert caregivers when symptoms are problematic |



USCInstitute for Creative Technologies # fitbit

Google

From Deloitte LLC 2015



Gamification

 Brown et al. (1997) designed a game to help kids manage diabetes and led to a 77 percent reduction in urgent care visits



- Accenture reports 7 key elements to gamification:
 - 1. status,
 - 2. milestones,
 - 3. competition,
 - 4. rankings,
 - 5. social connectedness,
 - 6. immersion reality, and
 - 7. personalization



Accenture, Why gasification is serious business

Brown, S. J., Lieberman, D. A., Gemeny, B. A., Fan, Y. C., Wilson, D. M., & Pasta, D. J. (1997). Educational video game for juvenile diabetes: Results of a controlled trial. Informatics for Health and Social Care, 22(1), 77-89.



The future of operations

Sample Use Cases

Workforce

Improved productivity



Aethon TUG Robots – Smart, autonomous robots substitute for the labor needed to haul and transport materials & clinical supplies augmentation **Evena -**Technic provide definition

Evena – Technician glasses provide highdefinition, realtime images of vascular anatomy to enable fast, precise IV access Research



IBM and Mayo Clinic – using artificial intelligence to more accurately match patients with appropriate clinical trials





Case study: Figure 1





Project ideas

- Intelligent EMR: differential diagnosis
- Model-building from unstructured data
 - Signs of neuropsychiatric issues in social media (e.g., Reddit)
- HealthKit-enabled applications
 - Smartwatch application (e.g., COPD)
- Search: A better 'Dr. Google'
 - CARE-RATE specifically designed for carers of people with dementia

••••



Resources 1

- Apple <u>ResearchKit</u> (free) or <u>HealthKit</u> (not free)
- IBM Watson
- Toronto Notes (1.3K pages)
- ¥ <u>UpToDate</u> (not free)
- emotiv EEG





Resources 2

EMR/mySQL

* '10K patients',

36K admissions, and 11M lab observations

 i2b2 challenges around smoking, obesity, and medication (67MB)

| PatientID | AdmissionID | PrimaryDiagnosisCode | PrimaryDiagnosisDescriptio n |
|--|-------------|----------------------|--|
| E74E9DF1- D8FD-41BC-8CDE-226CFE 318E0B | 1 | E09.42 | Drug or chemical induced diabetes mellitus with neurological complications with diabetic polyneuropathy |
| E74E9DF1- D8FD-41BC-8CDE-226CFE 318E0B | 2 | O29.123 | Cardiac failure due to anesthesia during pregnancy, third trimester |
| E74E9DF1- D8FD-41BC-8CDE-226CFE 318E0B | 3 | M84.561 | Pathological fracture in neoplastic disease, right tibia |

| PatientID | AdmissionID | LabName | LabValue | LabUnits | LabDateTime |
|--|-------------|-------------------------|----------|----------|----------------------------|
| 915BC24E-8C44- 4D33-A386- CEA965B83F32 | 1 | CBC: HEMATOCRIT | 40.7 | % | 1946-09-07 22:20:26.677 |
| 915BC24E-8C44- 4D33-A386- CEA965B83F32 | 1 | METABOLIC: ANION GAP | 8.4 | mmol/L | 1946-09-07 11:52:58.600 |
| 915BC24E-8C44- 4D33-A386- CEA965B83F32 | 1 | CBC: LYMPHOCYTES | 4.7 | k/cumm | 1946-09-07 06:08:57.303 |
| 915BC24E-8C44- 4D33-A386- CEA965B83F32 | 1 | CBC: HEMOGLOBIN | 15.9 | gm/dl | 1946-09-07 19:16:10.057 |



Resources 3

| Dataset | Link | Description |
|--|---|---|
| i2b2 Informatics for Integrating Biology & the Bedside | <u>https://www.i2b2.org/NLP/</u> DataSets/Main.php | Clinical notes used for clinical NLP challenges 2006 Deidentification and Smoking Challenge 2008 Obesity Challenge 2009 Medication Challenge 2010 Relations Challenge |
| Computational Medicine center | http://www.people.vcu.edu/ ~btmcinnes/projects/ icd9cm.html | Classifying Clinical Free Text Using Natural Language Processing |
| Texas Hospital Inpatient Discharge | https://www.dshs.texas.gov/ thcic/hospitals/ Inpatientpudf.shtm | Patient: hospital location, admission type/ source, claims, admit day, age, icd9 codes + surgical codes |
| National (Nationwide) Inpatient Sample (NIS) | https://www.hcup-us.ahrq.gov/ nisoverview.jsp | NIS is the largest publicly available all-payer inpatient health DB Unweighted, it contains more than 7 million hospital stays each year. Weighted, it estimates more than 35 million hospitalizations nationally. |

Start on your report

- Pick a venue for your report and build your report towards it.
 E.g., The BMJ, NIPS conference
- If your goal is an app on an app-store, go for it.

If you intend to involve or recruit other humans — let me know asamfp!



How data are currently stored and used

Electronic medical records

How humans and computers currently share medical data

| MIMS (IMS, INTERNALMEDICI | NE) (Patient: ADAMS, JENNET) |
|------------------------------|---|
| Action View Setup Activities | Billing Reports Utilities Windows Help |
| 2 2 39 😕 😢 🕵 | ■ 4 5 5 5 5 5 5 1 1 1 1 1 1 1 1 1 1 1 1 1 |
| 🔁 🖗 📝 🖗 🗞 14-4 | • • • • • • • • • • • • • • • • • • • |
| 🕅 Visit Note (Feb 24, 2010 7 | of 7) (Supervising: RD) |
| ADAMS, JENNET | 0 10 10 Female 41 yr(s) 100-00-1032 NKDA |
| General 9 🤅 | Feb 24, 2010 (Procedure: New Patient Case: General) |
| | |
| Complaint 2 | General: |
| Current Medication 2 | Office: Riverbend Medical Group of Bastrop |
| ROS 2. C | Provider: Ronald Davidson, M.D. |
| Medical History 🕺 🔍 | Encounter Date: Feb 24, 2010 |
| Family History 🕺 🕄 | Patient: Adams Jennet (PT00001026) |
| Social History 🛛 🕄 🔍 | Gender: Female DOB: Feb 26, 1969 Age: 40 year 11 mg |
| Vital Signs 🛛 🗞 🕄 | Address: 100 Smith St, Columbia SC 29205 |
| Examination 🗞 🕄 | Insurance: Aetna HMO |
| Procedures 🔋 🕄 | |
| Diagnosis 🗞 🕄 | Complaint: |
| Prescription 🗞 🕄 | Abdominal pain: IENNET complains of abdominal pain. Symptom(s) started 2 week(s) |
| Diagnostic/Lab 📐 🕅 🕄 | moderate. It is associated with fever but not hematuria. |
| Office Test 🛛 🕅 🔍 | |
| Plan 🕅 🕄 | Current Medication: |
| Immunization 🗞 🔂 | Amoxil 500 Mg Capsule SIG: Take 1 three times a day. |
| Careplan 🗞 💽 | (2) Avalide 150-12 5 Mg Tablet, SIG: 1 every 6-8 hours as need (3) Avalide 150-12 5 Mg Tablet, SIG: 1 every morning. |
| Super Bill 🛛 🖏 | (b). Availate 100 12.0 Hg rablet old. Tevely monning |
| | ROS: |
| | General: (-) fever, (-) chills, (-) night sweats, (-) fatigue, (-) weakn |
| | Skin: (-) rashes, (-) lumps, (-) itching, (-) dryness, (-) acne, (-) disc |
| | Nose and Sinuses: (-) frequent colds. (-) nasal stuffiness or itchine |
| | Mouth and Throat: (-) bleeding gums, (-) toothache, (-) odd taste |
| | (-) dentures use. |
| | Neck: (-) swollen glands, (-) enlarged thyroid, (-) neck pain. |
| | Respiratory: (-) cough, (-) hemoptysis, (-) shortness of breath, (-) |
| | dyspnea. (-) shortness of breath. |
| | Gastrointestinal: (+) abdominal pain. |
| | Urinary: (-) dysuria, (-) frequency, (-) urgency, (-) hesitancy, (-) pc |
| | (-) change in urinary habits. |
| | Musculoskeletal: (-) muscle pain, (-) joint pain, (-) bone pain. |
| | neurological deficits. |
| | |
| _ _ | Examination: |
| CPE PB1 | General Appearance: The patient is well-developed, well-nourished |
| CPE PB 2 | place, and person. The patient ambulates to the examination room w without difficulty or evidence of pain. |
| CPE PB3 | Skin: Gross inspection of skin demonstrates no evidence of abnorma |
| GENERIC IMAGEING RE | ENT: Both ears appear grossly normal without any obvious anomaly. |
| GENERIC VASCULAR S1 | mucosa, oral mucosa, salivary glands and pharynx all appear to be n |
| URINALYSIS | Neck: Neck reveals full range of motion without pain. There is no sig |
| | enlarged and does not have a palpable nodule. There is no evidence |
| | respiratory, congs are clear to adsourcation and percussion. No write |

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Data deluge

Sources of the data deluge



Advances in **analytical** and **computing** techniques coupled with the explosion of data in healthcare can help uncover leading clinical practices, shrink research discovery time, streamline administration, and offer new personalized engagement at an industrial scale that align people's decisions.

* HP Autonomy, Transitioning to a new era of human information, 2013

** Steve Hagan, Big data, cloud computing, spatial databases, 2012



Data



- Recall: (aka sensitivity, true positive rate) the proportion of positives that are correctly identified as such.
- Precision: the proportion of identified elements that are true positives.



Specificity: (aka true negative rate) the proportion of negatives that are correctly identified as such



Billing data 1

- The International Classification of Diseases (ICD) is a hierarchical terminology of diseases, signs, symptoms, and procedure codes maintained by the World Health Organization (WHO).
 - * In the US, most people use ICD-9, and the rest of world use ICD-10.
 - **Pros**: Universally available.
 - **Cons**: medium recall and medium precision for characterizing patients.
 - (250) Diabetes mellitus
 - (250.0) Diabetes mellitus without mention of complication
 - (250.1) Diabetes with ketoacidosis
 - (250.2) Diabetes with hyperosmolarity
 - (250.3) Diabetes with other coma
 - (250.4) Diabetes with renal manifestations
 - (250.5) Diabetes with ophthalmic manifestations
 - (250.6) Diabetes with neurological manifestations
 - (250.7) Diabetes with peripheral circulatory disorders
 - (250.8) Diabetes with other specified manifestations
 - (250.9) Diabetes with unspecified complication



Billing data 2

- The Current Procedural Terminology (CPT) was created by the American Medical Association for billing purposes.
 - * CPT is similar to ICD, except it identifies services rendered, not the diagnosis.
 - Category I: evaluation, anesthesia, surgery, radiology,...
 - * Category II: no value (e.g., patient safety).
 - Category III: emerging technology
 - **Pros**: High precision
 - Cons: Low recall

Codes for Evaluation and Management: 99201-99499

(99201 - 99215) office/other outpatient services

(99217 - 99220) hospital observation services

(99221 - 99239) hospital inpatient services

(99241 - 99255) consultations

(99281 - 99288) emergency dept services (99291 - 99292) critical care services





Lab results

- The standard code for labs is the Logical Observation Identifiers Names and Codes (LOINC) -
- Challenges for labs: 100
 - Many lab systems still use local dictionaries for encoding
 - Diverse numeric scales on different labs T
 - Often need to map to normal, low, or high ranges in order to be useful for analytics 1000
 - Missing data
 - not all patients have all labs
- The order of a lab test can be predictive, for example, **BNP** indicates high likelihood of heart failure. -----

| Time | Lab | Value |
|-----------------------|-------|-------|
| 1996-03-15 12:50:00.0 | BUN | 16.0 |
| 1996-03-15 12:50:00.0 | HDL-C | 37.0 |
| 1996-03-15 12:50:00.0 | K | 4.5 |
| 1996-03-15 12:50:00.0 | Cl | 102.0 |
| 1996-03-15 12:50:00.0 | Glue | 86.0 |
| 1996-03-15 12:50:00.0 | CO2 | 29.0 |
| | 43 | |



Clinical notes

- Clinical notes contain rich and diverse source of information.
- Challenges for handling clinical notes include:
 - Ungrammatical, short phrases; abbreviations; typos; Semi-structured
- Structured template: SOAP notes: Subjective, Objective, Assessment, Plan

| OBJECTIVE 250.00 DM, CONTROLLED, TYPE II 585.3 Kidney DZ, Chronic (GFR>30-59), STG III 412 OLD MYOCARDIAL INFARCT 715.09 GENERAL OSTEOARTHROSIS 427.31 ATRIAL FIBRILLATION | SUBJECTIVE ANXIETY STATE NOS 300.00 DEPRESSIVE DISORDER NEC311 ATRIAL FIBRILLATION 427.31 OLD MYOCARDIAL INFARCT 412 | | |
|--|--|------|------|
| ASSESSMENT BP 122/68 PULSE 78 TEMP (Src) 98.1 (oral) Resp 22 Wt 227 lbs Abdomen: soft, non-tender, obese and no masses or organomegaly Back: No CVA tenderness Extremeties: No edema | PLAN Continue present medication(s) Referral(s) to: eye Injection(s) ordered: b12 Schedule labs: Labs on return | More | late |

Medication

- The standard code is the National Drug Code (NDC) by Food and Drug Administration (FDA), which gives a unique identifier for each drug.
 - Not used universally by EMR systems.
 - * Quite specific: drugs with the same ingredients but different brands have different NDC
- RxNorm: a normalized naming system for generic and branded drugs by National Library of Medicine
- Medication data can vary in EMR systems
 - Can be in both structured or unstructured forms.
- * Availability and completeness of medication data vary.
 - Inpatient medication data are complete, but outpatient medication data are not.
 - Unclear whether patients actually filled those prescriptions.



Qualities of EMR data

| | ICD | CPT | Lab | Medication | Notes |
|--------------|---|--------------------------------------|-------------------------------------|---|--------------------------------------|
| Availability | High | High | High | Medium | Medium |
| Recall | Medium | Poor | Medium | Inpatient: High Outpatient: Mixed | Medium |
| Precision | Medium | High | High | Inpatient: High Outpatient: Mixed | Medium high |
| Format | Structured | Unstructured | Mostly structured | Both | Unstructured |
| Pros | Easy to work with; approximates disease | Easy to work with; high precision | High data validity | High data validity | More detail about thought process |
| Cons | Can be applied only in screening | Missing data | Data normalization and ranges | Prescriptions not necessarily filled/ taken | Difficult to process |

JC Denny Chapter 13: Mining Electronic Health Records in the Genomics Era. PLoS Comput Biol. 2012 December; 8(12):

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Interacting with EMRs

| 👰 IMS (IMS, INTERNALMEDI | CINE) (Patient: ADAMS, JENNET) | _ # × |
|------------------------------|--|--------------------|
| Action View Setup Activities | Billing Reports Utilities Windows Help A:4 D:2 F:6 H:12 | 2. R: 103. A. 100. |
| 2 2 39 😕 🕑 🖞 | (C & ⊠ Ø 6 6 6 6 E 8 6 € 8 8 P 2 6 R 2 6 R 9 6 0 6 0 • | |
| 4 6 9 9 6 8 | * * * * * * * * * * * * * * * * * * * | |
| Wisit Note (Feb 24, 2010 | 7 of 7) (Supervising: RD) | - O X |
| ADAMS, JENNET | 0 40 k 47 [Female] 41 yr(s) 100-00-1032 NKDA | Pt. Credit: 30.00 |
| General 9.6 | Feb 24, 2010 [Procedure: New Patient Case: General] OReminder NA | |
| Allerov 2. | | |
| Complaint 9. | General: | |
| Current Medication 2 | Office: Riverbend Medical Group of Bastrop | |
| ROS % | Provider: Ronald Davidson, M.D. | |
| Medical History & | Encounter Date: Feb 24, 2010 | |
| Family History & | Patient: Adams Jonnet (PT00001026) | (P) Deserves |
| Social History & | Gender: Female DOB: Feb 26, 1969 Age: 40 year 11 month Race: African-American | Document |
| Vital Signs 🛛 🗞 🕄 | Address: 100 Smith St, Columbia SC 29205 | Since Last |
| Examination % | Insurance: Aetna HMO | Visit |
| Procedures % | | Show Link |
| Diagnosis 🕺 | Complaint: [Prev. Yisit] [Add/EditNote] | T Go To |
| Prescription % | ENNET complains of abdominal pain. Symptom(s) started 2 week(s) ago. She describes her pain as bursting, darting. Patient's symptoms are | ▼ Option |
| Diagnostic/Lab | moderate. It is associated with fever but not hematuria. | D Dia |
| Office Test | | S Print |
| Plan 🗞 | Gurrent Medication: [Add/Edit Note] | - Fax |
| Immunization % | (1). Amoxil 500 Mg Capsule SIG: Take 1 three times a day. | 🥵 Super Bill |
| Careplan % | (2). Mylanta Geicap SIG: Take one tablet every 5-8 nours as needed for pain | Follow Up |
| Super Bill 6 | | Letter |
| | ROS: [Prev. Visit] [Add/EditNote] | 🔒 Sign Off |
| | General: (-) fever, (-) chills, (-) night sweats, (-) fatigue, (-) weakness, (-) changes in appetite or weight. | Copy From |
| | Skin: (-) rashes, (-) lumps, (-) itching, (-) dryness, (-) acne, (-) discoloration, (-) recurrent skin infections, (-) changes in hair, nails or moles. | * Template |
| | Nose and Sinuses: (-) frequent colds, (-) variago, (-) diaziness, (-) earache, (-) ear infection, (-) ear discharge, (-) disc of hearing alds. | * Prv. Visit |
| | Mouth and Throat: (-) bleeding gums, (-) toothache, (-) odd taste sensations, (-) sores on tongue, (-) frequent sore throat, (-) hoarseness, | 民 Note |
| | (-) dentures use. | 😒 Image |
| | Neck: (-) swollen glands, (-) enlarged thyroid, (-) neck pain. | SECG Spire |
| | Respiratory: (-) cough, (-) hemoptysis, (-) shortness of breath, (-) cyanosis, (-) wheezing, (-) nocturnal choking or gasping, (-) TB exposure. | Reminder |
| | dyspnea, (-) shortness of breath. | Analysis |
| | Gastrointestinal: (+) abdominal pain. | * Template |
| | Urinary: (-) dysuria, (-) frequency, (-) urgency, (-) hesitancy, (-) polyuria, (-) nocturia, (-) hematuria, (-) urinary incontinence, (-) flank pain, | * Flowsheet |
| | (-) change in urinary habits. | * Vital |
| | Neurological: (-) muscle pain, (-) joint pain, (-) bone pain. Neurological: (-) numbress (-) tingling (-) tremors (-) seizures (-) vertige (-) discipase (-) memory loss (-) any feeal or diffuse | *Lab |
| | neurological deficits. | * Monitor |
| | | * Diabetes |
| | Examination: [Prev. Yisit] [Add/Edit Note] | 🗞 CHDP |
| CPE PB1 | General Appearance: The patient is well-developed, well-nourished, and in no cardiorespiratory distress. She is alert and oriented to time, | |
| CPE PB 2 | without difficulty or evidence of pain. | |
| CPE PB3 | Skin: Gross inspection of skin demonstrates no evidence of abnormality. Hair and nails are also normal. Skin is warm and drv. | |
| GENERIC IMAGEING R | ENT: Both ears appear grossly normal without any obvious anomaly. Both ear drums appear normal, auditory canals are normal. Nasal | |
| GENERIC VASCULAR S | mucosa, oral mucosa, salivary glands and pharynx all appear to be normal. | |
| URINALYSIS | Neck: Neck reveals full range of motion without pain. There is no significant lymphadenopathy or mass. Trachea is midline. The thyroid is not | |
| | Respiratory: Lungs are clear to auscultation and percussion. No wheezes, rales, rules or rhonchi are noted | |
| | respiratory resings are used to association and percession, no mineces, rates, rates, rates or monicin are noted. | 4 |

More later...



Certified EMRs in Ontario

| Offering | Vendor | Туре | Status | |
|--|--------------------------------|---------|---------------------------|--|
| ABELMed EHR - EMR/PM v12 | ABELMed Inc. | LOCAL | v12.9 | |
| Accuro EMR CMS4 - ASP | QHR Technologies Inc. | ASP | CMS4 2014.5 | |
| Accuro EMR CMS4 - Local | QHR Technologies Inc. | (IOCAL) | CMS4 2013.9 | |
| Clinic Information System (CIS) - Complete EMR v8.0 - Clinic Edition | P&P Data Systems | | v8.0.068 VCN Available | |
| Clinic Information System (CIS) - Complete EMR v8.0 - Enterprise Edition | P&P Data Systems Inc. | (LOCAL) | v8.0.068 VCN Available | |
| EMR Advantage 3.2 | Canadian Health Systems Inc | (LOCAL) | v3.21.18 | |
| GlobeMed v2.0 | Alpha Global iT Inc. | (LOCAL) | v2.07 VCN Available | |
| Indivicare 4 | Indivica Inc. | ASP | v4.0.1 | |



Certified EMRs in Ontario (cont.)

| Offering | Vendor Type | | Status | |
|---------------------------------------|--|---------|--------------------------|--|
| Med Access EMR v4.3 | TELUS Health Solutions | (LOCAL) | v4.5 SP32 | |
| Nightingale On-Demand v9.0 - ASP | Nightingale Informatix Corporation | ASP | v9.2.4 | |
| Nightingale On-Demand v9.0 - Local | Nightingale Informatix Corporation | (LOCAL) | v9.2.3.1 | |
| OSCAR v15* | OSCAR EMR | LOCAL | v15 | |
| PS Suite v5.2 - ASP | TELUS Health Solutions | | v5.2.532 | |
| PS Suite v5.2 - Local | TELUS Health Solutions | (LOCAL) | v5.2.550 | |
| YES EMR v2.0 | YES Medical System | (LOCAL) | v2.0 BLD Sept 16.2013 | |
| YMS EMR v8.7 + 4.5 | YMS | LOCAL | v8.73 + 4.5.3.0 | |



Nightingale, e.g.

| Ightingale | Search patient charts by name or ID Q Show recent patients » | Lisa Jackson, MOA 👻 | Primary Care 👻 🕜 |
|---------------------|--|--|-----------------------|
| Back | binson, Brian Male 55 years (03/01/1960) PP: (716) 213-4578 ID: 1 | Patient Options 💌 | Encounter in progress |
| Open Items Summar | ry Timeline Encounters Labs Medications More | | PATIENT NOTE (Show) |
| Show as of 03/22/ | 2015 Print/Send | Encounter Note | Sign Apply Actions |
| Summary last r | NT 03/23/2015 - Coronary Artery Disease with Dr. Charles | SYMPTOMS Chest Pain, Edema, Fatigue RISK STRATIFICATION Select all that appl | ly × sment |
| VITALS No Vitals Re | scorded Craph | DIAGNOSES & HISTORY Chest Pain Dyspnea Pretest likelihood of CAD Very Low Low Palpitations | |
| ALLERGIES | No Known Drug Allergies | Heart Sounds Si Si Syncope | |
| PROBLEM LIST | HYPERTENSION Diagnosis: 401 - ESSENTIAL HYPERTENSION * | Lungs Clear Cr Edema +1 +2 | |
| | Diagnosis: 250 - 250 - DIABETES MELLITUS * CORNEAL NEOVASCULARIZATION * Diagnosis: 3706 - CORNEAL NEOVASCULARIZATION * | Murmurs Grade Mitral S/D Aortic S/D Other Fluid Volume Euvolemic Dry Overloaded | |
| MEDICATION | Start date not entered Metformin (500mg, Tablet, Oral) Take 1 Tablet Oral every morning in the morning | | |



OSCAR, e.g.

| Preventions • HV Social History • HV • Volution • Charles PR • Hu • Opportes PR • Hu • Opportes PR • Paul Color • Opportes PR • Ible Reg 1007 • • • • • • • • • • • • • • • • • • • • • • | MRP Dr. doctor osca | rdoc <u>TEST, PATIEN</u> | T M 25 years 905-123-0456 Next Appt | : <u>Calculators</u> <u>Tem</u> | plates | | | | |
|---|------------------------|--------------------------|--|---------------------------------|------------------|----------------|------------------------|---------------------------|-----------------|
| Pixe Control to PCR Td Control to PCR Pixe Pixe Pixe Control to PCR Pixe Pixe Pixe Pixe <tr< th=""><th>Preventions</th><th>+</th><th>Social History</th><th>+</th><th>Medical History</th><th></th><th>+</th><th>Allergies</th><th>22.0</th></tr<> | Preventions | + | Social History | + | Medical History | | + | Allergies | 22.0 |
| Intermedia Concernet SPR Td Fu View Takler Call Concernet Section 2 One forsal 100 Oby33 Repeats 0 Decements Call Concernet Section 2 Decement Section 2 Concernet Concernet Section 2 Decement Section 2 Concernet Concernet Section 2 Decement Concernet Section 2 | | | | | | | | BLACK ALDER | 22-Dec |
| Implementer Culture Culture <td>chlamydia</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>CA2</td> <td>22-Dec</td> | chlamydia | | | | | | | CA2 | 22-Dec |
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Ethics in EMRs

- New US regulations passed under the Health Insurance Portability and Accountability Act (HIPAA) permit patients to request and receive their medical records electronically.
 - These regulations can help patients by reducing the cost of obtaining accessible records, including otherwise 'hidden' information.
- 45 CFR §164.524 is effective as of 25 March 2013 and requires that providers who maintain their patient records in electronic form must, on request by the patient, provide the records in an electronic format acceptable to the patient if the record is "readily producible" in that format.
 - The provider may charge a reasonable, cost-based fee, which may include the the device (CD-ROM or USB device), labour costs, and postage.



Some artificial intelligence

Clinical decision support systems (CDSSs)

Typical ways intelligent systems augment EMRs





Definition of CDSS

 A working definition has been proposed by Dr. Robert Hayward of the Centre for Health Evidence:

"Clinical Decision Support systems link health observations with health knowledge to influence health choices by clinicians for improved health care"



General structure of CDSSs





Types of CDSS

Knowledge-based:

- Most CDSS consist of three parts:
 - the knowledge base contains the rules and associations of compiled data, which traditionally took the form of IF-THEN rules (e.g., IF drug(X) AND drug(Y) THEN alert(patient),
 - an inference engine combines the rules from the knowledge base with the patient's data, and
 - a mechanism to communicate to show results and accept new input and rules.

Non-knowledge-based:

 As you might expect, the knowledge base and inference engines are typically replaced by either neural networks or genetic algorithms.



Effectiveness 1

- A 2005 systematic review by Garg et al. of 100 studies concluded that CDSSs improved practitioner performance in 64% of the studies. The CDSSs improved patient outcomes in 13% of the studies.
- The CDSS is integrated into the clinical workflow rather than as a separate log-in or screen.
 - I.e., the CDSS provides decision support at the time and location of care, rather than prior to or after the patient encounter.
 - The CDSs provides (active voice) recommendations for care, not just assessments.



Effectiveness 2

- Maintenance: A core challenge is the difficulty in incorporating an extensive quantity of clinical research on an ongoing basis.
 - ✤ Each year, >>10K clinical trials are published.
 - Currently, each of these studies must be manually read, evaluated for legitimacy, and incorporated accurately.



Effectiveness 3

- **Evaluation:** CDSSs must demonstrably improve clinical workflow or outcome.
 - The evaluation depends on the CDSS's purpose.
 - E.g., a *diagnostic* CDSS may be rated by the accuracy of its classification of disease (as compared to physicians or other CDSSs).
 - E.g., an evidence-based medicine system may be rated by a high incidence of patient improvement, or financial considerations of care.



Examples

- Zynx Health the most prominent organization in the CDSS marketplace, whose CDSS is linked to a statistically significant percentage of hospital discharges nationwide.
- MYCIN, one of the first expert systems to be developed in the 1970s, it does ethiological diagnoses of bacterial diseases.
- CADUCEUS, a medical expert system that could diagnose 1000 diseases.
- Internist-I, a computer-assisted diagnostic tool.



General structure of CDSSs





Risk analysis

* If we want to regress on data $x \in \mathbb{R}^{n \times p}$ (with *n* observations and *p* covariates) and add explicit 'knowledge-driven' features $x \in \mathbb{R}^{n \times q}$ to a corresponding response $y \in \mathbb{R}^{n}$, we want to measure the fitness *F* of α :

$$F(\alpha) = \frac{1}{2} \|y - x\alpha\|^{2} + \frac{\beta}{4} \left[\sum_{i=1}^{p} \sum_{j=1}^{p} (\alpha_{i}\alpha_{j}x_{i}^{T}x_{j})^{2} + \sum_{i=1}^{p} \sum_{j=p+1}^{p+q} (\alpha_{i}\alpha_{j}x_{i}^{T}x_{j})^{2} \right] + \lambda \|\alpha\|_{1}$$

Model error
Correlation among
data-driven features
Correlation among data-
and KB-driven features

Luo, D., Wang, F., Sun, J., & Markatou, M. (2012). SOR: Scalable Orthogonal Regression for Non-Redundant Feature Selection and its Healthcare Applications. SIAM Data Mining ..., 950–961. http://doi.org/10.1137/1.9781611972825.50



Risk analysis



- AUC significantly improves as complementary data driven risk factors are added into existing knowledge based risk factors.
 - * A significant AUC increase occurs when we add first 50 data driven features

Jimeng Sun, Jianying Hu, Dijun Luo, Marianthi Markatou, Fei Wang, Shahram Ebadollahi, Steven E. Steinhubl, Zahra Daar, Walter F. Stewart (2012). Combining Knowledge and Data Driven Insights for Identifying Risk Factors using Electronic Health Records. AMIA



Lorem Ipsum Dolor

Challenges to adoption

Things to consider for your projects



Initializing the procedure

In the short term, intelligent decision support systems will continue to be used, but perhaps only to limited degrees.



Modernizing Medicine



InTouch Health+ iRobot

- Modern AI deals with unstructured data (e.g., images, text in medical records, patient speech) where 'noise' almost guarantees errors.
- There are also institutional barriers to overcome...





Regulation time

- * In the US, the FDA recognizes medical devices and permits their sale.
 - About 99% of new devices are cleared if they are "substantially equivalent" to existing devices.
 - Otherwise, despite guidance released in 2012, new devices must go through very rigorous "premarket approval", sometimes requiring clinical trials.
 Devices then fall into three classes:
 - Class I devices are low risk; they do not support or sustain life.
 - E.g., dental floss
 - Class II devices do not cause harm if used as intended.
 - E.g., acupuncture needles, power wheelchairs.
 - Class III devices are high risk and subject to the highest scrutiny
 - E.g., replacement heart valves.



Regulation time

- IBM has been lobbying in Washington for years to convince regulators that Watson does not need approval "because doctors make a final diagnosis"
 - H.R.6 "21st Century Cures Act" passed House 344-77
 (10 July 2015), read twice in Senate, passed to Committee...





Privacy

- One-fifth of smartphone owners had health apps in 2012.
- 7% of primary care physicians recommended a health app.
- The US Food and Drug Administration has approved the prescription of some apps.
- Health apps can transmit sensitive medical data, including disease status and medication compliance. Privacy risks and the relationship between privacy disclosures and practices of health apps are understudied.





- * Blenner et al. (2016) identified 271 diabetes apps and chose a random sample of 75 for analysis.
 - Within 6 months, 60 apps became unavailable, leaving 211 apps in the sample and 65 apps in the subset.
 - Most of the 211 apps (81%) did not have privacy policies. Of the 41 apps (19%) with privacy policies, not all of the provisions actually protected privacy (eg, 80.5% collected user data and 48.8% shared data).
 - Only 4 policies said they would ask permission to share data. These authorized collection and modification of sensitive information, including tracking location (17.5%), activating the camera (11.4%), activating the microphone (3.8%), and modifying or deleting information (64.0%).
 - In the subset, sensitive health information from diabetes apps (eg, insulin and blood glucose levels) was routinely collected and shared with third parties, with 56 of 65 apps (86.2%) placing tracking cookies; 31 of the 41 apps (76%) without privacy policies, and 19 of 24 apps (79%) with privacy policies shared user information. Of the 19 apps with privacy policies that shared data with third parties, 11 apps disclosed this fact, whereas 8 apps did not.

Blenner, S. R., Köllmer, M., Rouse, A. J., Daneshvar, N., Williams, C., Andrews, L. B. (2016) Privacy Policies of Android Diabetes Apps and Sharing of Health Information. JAMA, 315(10), 1051.





the hippocratic oath



- * I swear to fulfill, to the best of my **ability** and **judgment**, this covenant:
 - I will respect the hard-won scientific gains of those physicians in whose steps I walk, and gladly share such knowledge as is mine.
 - I will apply, for the benefit of the sick, all measures which are required, avoiding those twin traps of over-treatment and therapeutic nihilism.
 - I will remember that there is art to medicine as well as science, and that warmth,
 sympathy, and understanding may outweigh the surgeon's knife or the chemist's drug.
 - I will respect the privacy of my patients, for their problems are not disclosed to me that the world may know...

