Belief Revision in
Coronary Artery Disease Risk Assessment

Introduction

Belief systems are a set of principles which is used to interpret our day to day reality. They are usually influenced by a number of factors. In this project, we look at the belief system of a medical diagnosis. This is also known as an expert system. In this situation we have a doctor, a patient and a disease to diagnose. Our aim is to successfully diagnose a patient's disease like a doctor would or simulate close to an exact situation at the doctors office. The system collects important information about a patient and updates/ changes its belief about the actual disease of a patient.We create a cognitive model of belief revision. This project targets a branch of heart disease which is coronary artery disease or CAD. We discuss the symptoms patients suffer from, look at their family history, what test should be carried out and if they actually have CAD or not. The more information we input into our system the better the belief revision process.

Background

According to the National Academy of Medicine, the diagnostic process is a "complex, patient-centered, collaborative activity that involves information gathering and clinical reasoning with the goal of determining a patient's health problem". Diagnosis involves a long series of information gathering and tests. Such information is needed for the doctor to form an initial hypothesis (belief) about a patient's disease. This belief constantly changes as more information is received, integrated and interpreted alongside previously formed beliefs. In the context of a coronary artery disease, for instance, the doctor could have initial beliefs based on their age. However, upon knowing eating habits, their beliefs could change significantly. The diagnostic cycle is more clearly shown in the diagram below. [1]

[1] National Academies of Sciences, Engineering, and Medicine. 2015. *Improving Diagnosis in Health Care*. Washington, DC: The National Academies Press.https://doi.org/10.17226/21794.

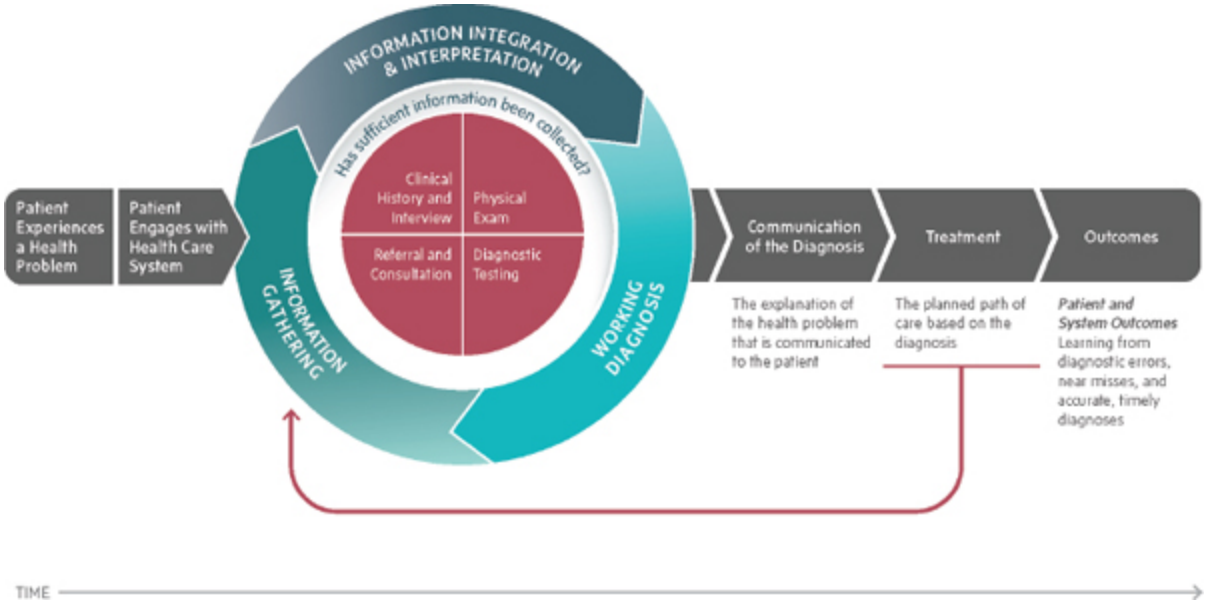

Figure 1: Diagnosis process. [2]

A doctor's diagnosis often starts with an initial perception of their patient. Sensory cues can indicate many things about a person's health. For instance, if the patient looks obese (which could indicate inactivity) or seems to be out of breath (which could indicate smoking/inactivity), then the doctor might be more inclined to believe that they have CAD. Other indicators include age. the older a person is the higher the chance a person is to experience a heart related condition. The risk of an organ damage or "narrowed arteries" increases due to age as well.[3] Sex could also alter a doctor's diagnostic process. While the symptoms seem pretty similar, women tend to exhibit more symptoms of upper body discomfort, fatigue and nausea, while men experience more chest pain and heart attacks. Women's risk increases after menopause, while men's risk increases after the age of 45. Race is also another factor. Black, Mexican American, Native American, Native Hawaiian and Asian Americans populations usually have a higher risk of CAD. High blood pressure, obesity and diabetes seems to be more prevalent within these populations.[4]

After such their initial perception, then the information gathering (an integral part of the diagnosis process) begins. The doctor starts off by communicating with the patient and asking them questions about their family history, lifestyle choices, symptoms etc. A typical doctor often

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[2] National Academies of Sciences, Engineering, and Medicine. *Improving Diagnosis in Health Care*.
[3] "Coronary Artery Disease." *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 5 June 2020, https://www.mayoclinic.org/diseases-conditions/coronary-artery-disease/symptoms-causes/syc-20350613 .
[4] "Coronary Artery Disease: Causes, Symptoms, Diagnosis & Treatments." *Cleveland Clinic*, https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease.

bases his diagnosis on a set of categories agreed upon by the larger medical community. Depending on how aware a patient is about their disease, a doctor could have a different diagnostic process. If they come to the doctor with a prediction of what they have, a doctor might treat their symptoms as "checking off a list," since they already have a set of beliefs about what makes up a disease they are trying to diagnose. In the case that a patient is not sure about their disease, then the doctor has to form their own hypothesis based on the initial condition given to them. The latter process of diagnosis is more common and involves more belief revision (and still occurs even if the patient is more aware of their disease, as other diseases should also be considered).

Usually, this gives the doctor a good indication of the likelihood of the patient having CAD. Information about family history is often a great indicator of diseases. A family history of developing CAD earlier than the age of 50 is often an indication of genetic inclination towards the disease. [5] When it comes to lifestyle choices, exercise and eating habits are usually the main variables. For CAD, inactivity, poor eating habits, and smoking/drinking habits often lead to higher risk of CAD.

This diagnosis is usually partnered with more formal clinical testing (such as blood tests, EKG, CT scans etc.).[6] Such testing is important since they also show CAD even with the absence of symptoms. Doctors may order a Cardiac CT scan to detect the levels of calcium in the blood because calcium build up results in plaques which is a main cause of CAD. It can also be used to predict the risk of other heart diseases such as a heart attack based on the extent of the calcium build up. An example of what testing is used when there are no obvious symptoms to CAD is EKG. EKG is a non-invasive diagnostic test which records the electrical activity of the heart. It may assist in diagnosing other heart problems as well. It looks at the heart rhythm, size and muscle. It can also be used to make future comparisons to new information on a patient's heart condition.

Methods

<u>How do we represent the belief?</u>

We're representing the belief as if it were a doctor talking to a patient for the first time with their basic information in their hand. So we have a set of facts about each patient's basic information such as their name, age, sex, and ethnicity/race. We'll also have a "personal_history" rule which takes in any personal/family medical history such as past illnesses, or family history of illnesses. We'll also have the "lifestyle" rule which takes in each person's eating habits, smoking habits, and activity/exercise. Then we're going to have a "symptom" rule that takes in

[5] "Coronary Artery Disease." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 19 July 2021, https://www.cdc.gov/heartdisease/coronary_ad.htm.
[6] "Diagnosing Coronary Artery Disease." *Patient Care at NYU Langone Health*, https://nyulangone.org/conditions/coronary-artery-disease-in-adults/diagnosis.

each patient's account of their symptoms. This would include any chest pains/breathing difficulties, as well as their severity. Finally, we're going to take in tests for each patient, which measures their blood pressure, cholesterol level, blood sugar level, BMI, and ratio of waist/hips. The test rule will take in the test method (blood tests, EKGs, and CT scans), result, and reliability.

How do we reason with the belief?

The guidelines for diagnosing CAD can be pretty broad. As such, we're just going to focus on certain tests. Each person's basic facts, history, symptoms, and test results would be given a point based on the below table. Each "yes" would amount to 1 point.

1. Age:	**no** <50g.	**yes** 50g.>
2. smoking:	**no**	**yes**
3. family history of coronary artery disease:	no	**yes**
4. blood pressure	**no** < 139/40mmHg	**yes** >140/40mmHg
5. cholesterol:	**no** < 5,5 mmol/l	**yes** > 5,6 mmol/l
6. blood sugar:	**no** < 6,0 mmol/l	**yes** > 6,1 mmol/l
7. BMI :	**no** < 25 kg/m^2	**yes** >25 kg/m^2
8. the ratio of waist / hips:	m. **yes** >1,0 **no** < 0,9	w **yes** > 0,9 , **no** < 8, 9
9. physical activity:	**no** < 30 min. per day	**yes** > 30 min. per day

These points would be tallied up and be interpreted based on the following assessment:

Risk present	Expressed risk	highly expressed risk
1 – 3 points	4 -6 points	7–9 points

What are the conditions under which we will revise our beliefs?

Once the patient has been diagnosed, the code remembers and their result is stored as a predicate. As such, when they "visit" the doctor again, they only have two choices: put in new symptoms or order new tests. When they enter new symptoms, this would be added to their list of symptoms and their points would be recalculated. As such, their diagnosis would most likely change. When they order for new tests, then they need to enter which tests they want to reorder.

What are the techniques for revising such beliefs?

When the users enter new information such as new symptoms or new tests, their previous result is retracted from the codebase and replaced by the new result. With symptoms, this

happens by adding the new symptom to the codebase, retracting their previous result, then recalculating and reasserting their result. With tests, their results are recalculated and always replaced by the new test result (we're assuming that the new tests are always more reliable). And similar to entering new symptoms, their previous result is retracted and recalculated.

Discussion

In our model, we've modeled multiple situations involving multiple patients. Since the basic information about them are set (such as their age and sex), then there is no room for belief revision there. That is a known fact.

The problem with the basic information section of our code is that we only work with patients who are already registered with the doctor. It does not really simulate a real life situation where we have new patients with new basic information. Basically, we cannot diagnose patients outside our current patient records. Another limitation is that we cannot consider other heart related issues and diagnose to see if the patient actually has CAD or another related disease. Because CAD and other heart disease have very similar symptoms, in an ideal situation, the test result would enable the doctor to presume a different disease instead of letting the patient know their test does not show they have CAD. It's like "oh you are sick, it is not CAD though but you should definitely see a doctor about that" when we are simulating what a doctor-patient situation would look like. We can update what the doctor would believe, what heart disease a patient might have based on test results and how many positive test results are returned. Although we have a belief revision section for new symptoms, we could also have a belief revision section for different heart diseases. It would only further diagnose and treat CAD since that is our main idea. For instance heart arrhythmias have similar symptoms to CAD but the difference between both is slow or irregular heart rhythm.

Something we would add to our model would be a treatment section to better simulate an ideal cognitive model for a medical diagnosis situation. We just diagnose but do not offer a treatment, so it covers the model to a certain extent.

I believe that our computation model could be useful in specific situations, ie diagnosing coronary heart disease. We tried to imitate a patient's real-life visit to a doctor, but their interactions are fairly limited. When trying to examine the patient, the doctor only asks yes or no questions about symptoms that are specific for coronary heart disease. The patient can only answer yes/no to those questions. In reality, such examinations are more complicated than that. A patient would most likely explain more about their specific situation. The doctor might also use those to see whether or not the patient might have other diseases outside of CAD, whereas our model only checks if the patient has CAD or not. As such, if we had to change anything, then we would make the interaction more natural. Perhaps ask about their symptoms in general, instead of asking yes/no questions about symptoms that are specific to CAD. For each symptom, diagnose a disease and update the disease based on every new symptom added to the patient's record. The problem we face here is in order to diagnose CAD we need the test section and the type of test. We would therefore have to add a series of tests carried out for different heart diseases.

I do believe our model is useful as a cognitive model because it covers the basics of such a model. It collects previous data about a patient so we can update their diagnoses, change previous information collected and collect more symptoms related to CAD to better diagnose. We have our initial examination section which checks for CAD related symptoms. If a patient

has more than one symptom and has chest pain, we can go ahead and order a test. The order test section covers the type of test conducted for a patient a doctor would suspect to have CAD. If the test results are above the normal range then we make our diagnosis. While making our diagnosis we can also examine other factors like age. Using our diagnosis, we can then infer the CAD risk of a patient. Some patients encounter other symptoms which we may not be aware of, so we included a section for new symptoms. So new symptoms means that we would have to order new tests for our patient because now they have more related symptoms.

Conclusion

In conclusion, we were able to develop a cognitive model that mimics a doctor that is trying to diagnose coronary artery disease. Since we found that the diagnosis process is a constant process of belief revision through information retrieval and information integration from the patient, we created our model so it takes input from the patient through a pseudo-conversation with the "doctor". We created our model by storing some facts about each patient, and getting their symptoms and tests through user input. When users decide to enter new symptoms or new tests, their previous results are retracted and their new results are asserted. In general, I believe that our model is useful for the specific diagnosis of CAD. The limitation is that the interactions are fairly limited; we only ask yes/no questions specific to CAD, which does not reflect natural interactions between doctors and their patients. In the future, we wish to create a model that allows users to have more natural interactions with the "doctor" by analyzing their sentences/phrases, and perhaps expanding diagnosis beyond CAD.

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Appendix

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% How the diagnosis goes:
    % Call "hellodoctor" - asks patient for their name and
checks if they are in the database
    % If in database - check if they've already been diagnosed
        % If not diagnosed - go through initial examination
        % If already diagnosed - ask if they want to enter new
symptoms/enter new tests
    % Initial exmination: answer y/n to symptoms,
        % If y, then add to their list of symptoms
    % If symptom points >= 2, then order for tests -- else
diagnose as no CAD
    % After getting all test resuls - add points up
    % Use total points to make CAD risk analysis (using point
system from table)

% Patients
patient(jane).
patient(edima).
patient(tiffany).
patient(joseph).
patient(john).

%% Basic information about each patient
age(jane, 21).
age(edima, 20).
age(tiffany, 57).
age(joseph, 82).
age(john, 45).

sex(jane, female).
sex(edima, female).
sex(tiffany, female).
sex(joseph, male).
sex(john, male).

:- dynamic has_symptom/2.
:- dynamic current_patient/1.
:- dynamic already_diagnosed/1.
:- dynamic symptom_points/2.
:- dynamic total_points/2.

hellodoctor :- write("Welcome! Can we start with your name?"),
nl, check_patient_records.
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check_patient_records :- read(Name), patient(Name),
retract_name(Name).
check_patient_records :- write("I'm sorry. I only examine
patients in my current patient records."), !.

retract_name(Name) :- current_predicate(patient/1),
retractall(current_patient(patient(_))),
assert(current_patient(patient(Name))), path.
retract_name(Name) :- assert(current_patient(patient(Name))),
path.

path :- current_patient(patient(Name)),
current_predicate(already_diagnosed/1), already_diagnosed(Name),
write("Welcome back, "), write(Name), write("! Would you like to
enter new symptoms/order new tests? (new_symptoms/new_tests)"),
nl, choice.
path :- current_patient(patient(Name)), write("Hello, "),
write(Name), write("! Let's start you examination by asking a
few questions about your symptoms."), nl, initial_examination.


%% ---- INITIAL EXAMINATION ---- %%

initial_examination :- symptoms(L), check_symptoms(L),
check_points.

symptoms(L) :- findall(Symptom, symptom(Symptom), L). % Returns
a list of all symptoms

check_symptoms([]) :- !.
check_symptoms([H|T]) :- symptom_questions(H, Q), ask_symptom(H,
Q), check_symptoms(T).

ask_symptom(Symptom, Q) :- write(Q), nl, read(Y), Y = y,
current_patient(patient(Patient)), assert(has_symptom(Patient,
Symptom)).
ask_symptom(_, _) :- !.

check_points :- get_symptoms(L), calculate_points(L, 0).

calculate_points([H|T], TotalPoints) :- symptom_point(H, Point),
NewPoint is TotalPoints + Point, calculate_points(T, NewPoint).
calculate_points([], TotalPoints) :- TotalPoints >= 2,
order_tests, !.
calculate_points([], _) :- write("Not enough symptoms. You do
not have CAD."), !.
```

```
%% -- ORDERING TESTS -- %%

order_tests :- write("Ordering tests for more conclusive
results."), nl, get_test_results.

get_test_results :- tests(L), check_tests(L), make_diagnosis.
tests(L) :- findall(Test, test_type(Test), L). % returns a list
of all test types

check_tests([]) :- !.
check_tests([H|T]) :- ask_test(H), check_tests(T).

ask_test(Test) :- write("What is the patient's test result for
"), write(Test), write("?"), nl, read(Result),
current_patient(patient(Patient)), positive_test(Test, Result),
assert(has_symptom(Patient, Test)).
ask_test(_) :- !.

make_diagnosis :- current_patient(patient(Patient)), check_age,
calulate_total_points, total_points(Patient, TotalPoints),
interpret_points(TotalPoints),
assert(already_diagnosed(Patient)).

check_age :- current_patient(patient(Patient)), age(Patient,
Age), Age > 50, assert(has_symptom(Patient, age)).

calulate_total_points :- get_symptoms(L),
calulate_total_points(L, 0).
calulate_total_points([H|T], Total) :-
current_patient(patient(Patient)), has_symptom(Patient, H),
NewTotal is Total + 1, calulate_total_points(T, NewTotal).
calulate_total_points([_|T], Total) :- calulate_total_points(T,
Total).
calulate_total_points([], Total) :-
current_patient(patient(Patient)), assert(total_points(Patient,
Total)).

interpret_points(DiagnosisPoints) :- DiagnosisPoints = 0,
write("No CAD risk.").
interpret_points(DiagnosisPoints) :- DiagnosisPoints =< 3,
write("CAD risk present.").
interpret_points(DiagnosisPoints) :- DiagnosisPoints =< 6,
write("Expressed CAD risk present.").
interpret_points(DiagnosisPoints) :- DiagnosisPoints =< 9,
write("Highly expressed CAD risk.").
```

```
%% ---- BELIEF REVISION ---- %%

choice :- read(Choice), Choice = new_symptoms, new_symptoms.
choice :- new_tests.

rediagnose :- retract_total_points,
current_patient(patient(Patient)), check_age,
calulate_total_points, total_points(Patient, TotalPoints),
interpret_points(TotalPoints).

retract_total_points :- current_predicate(total_points/2),
current_patient(patient(Patient)), total_points(Patient, _),
retractall(total_points(Patient, _)).


%% -- NEW SYMPTOMS -- %%

new_symptoms :- display_current_symptoms, nl, write("What is
your new symptom?"), nl, read(NewSymptom), symptom(NewSymptom),
current_patient(patient(Patient)), assert(has_symptom(Patient,
NewSymptom)), rediagnose.
new_symptoms :- write("Entered symptom is not a CAD symptom.
Please try again. (Possible symptoms are: "), symptoms(L),
write(L), write(" )."").

display_current_symptoms :- get_symptoms(L), write("Here are
your current symptoms:"), write(L).
get_symptoms(C) :- current_predicate(has_symptom/2),
current_patient(patient(Patient)), findall(X,
has_symptom(Patient, X), C). % Returns list of all confirmed
symptoms for current patient


%% -- NEW TESTS -- %%

new_tests :- write("Which test are you entering for the
patient?"), nl, read(TestType), test_type(TestType),
ask_test(TestType), rediagnose.
new_tests :- write("Not a CAD test.").


%% UTILITIES %%

% Ask a bunch of yes or no questions to get the patients
diagnosis
```

```
symptom_questions(chestPain, "Are you experiencing any chest
pain or chest discomfort? (y/n)").
symptom_questions(inactivity, "Do you get less than 30 minutes
of exercise everyday? (y/n)").
symptom_questions(smoking, "Are you currently a smoker? (y/n)").
symptom_questions(familyHistory, "Do you have a family history
of coronary artery disease? (y/n)").

% Symptom points
symptom_point(chestPain, 2).
symptom_point(inactivity, 1).
symptom_point(smoking, 1).
symptom_point(familyHistory, 1).

% Initial symptoms
symptom(chestPain).
symptom(inactivity).
symptom(smoking).
symptom(familyHistory).

%% Test types
test_type(bloodPressure).
test_type(cholesterol).
test_type(bloodSugar).
test_type(bmi).
test_type(waistHipRatio).

%% Tests
positive_test(bloodPressure, Result) :- Result > 140.
positive_test(cholesterol, Result) :- Result > 5.6.
positive_test(bloodSugar, Result) :- Result > 6.1.
positive_test(bmi, Result) :- Result > 25.
positive_test(waistHipRatio, Result) :-
current_patient(patient(Patient)), sex(Patient, male), Result >
1.0.
positive_test(waistHipRatio, Result) :-
current_patient(patient(Patient)), sex(Patient, female), Result
> 0.9.
```