PROJECT REPORT

HEALTHCARE TREATMENT RECOMMENDATION

Course: Intelligent Systems - Agents and Reasoning

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1. INTRODUCTION

In this project we designed and implemented a small expert system for healthcare treatment recommendation. The main idea is to support the decision about which treatments a patient should receive based on logical rules instead of ad-hoc programming. The project follows the structure given in the ISAR course: we first translate a natural language description of constraints into first-order logic (FOL), and then use the IDP system to compute models that satisfy these constraints.
The expert system works on a simplified medical domain with a finite set of patients, diseases, symptoms and treatments. For each patient, the system has information about which diseases they have, which symptoms they show, their age, possible allergies, and whether they belong to a high-risk group. The logical theory then reasons about this information to decide which treatments are recommended. Important aspects such as allergies, drug incompatibilities, treatment limits for elderly patients, and basic antibiotic stewardship are all expressed as FOL constraints.
A key requirement of the project is not only to encode the given constraints, but also to extend the expert system with additional rules that make the recommendations more realistic and medically reasonable. In our solution we added several constraints about risk, age, symptom coverage and disease priorities. The final IDP code, together with the FOL formulas and this report, demonstrates that the system behaves as expected and that logical modelling is a useful tool for analysing and explaining expert systems.

2. DOMAIN AND VOCABULARY

We use four main types: Patient, Disease, Symptom and Treatment. The concrete diseases are: flu, pneumonia, asthma, hypertension. The concrete treatments are: paracetamol, antibiotics, bronchodilator, amlodipine, ibuprofen. We use the following predicates:

- $HasDisease(p, d)$ $-$ $patient\ p\ has\ disease\ d$
- $HasSymptom(p, s)$ $-$ $patient\ p\ has\ symptom\ s$
- $Allergic(p, t)$ $-$ $patient\ p\ is\ allergic\ to\ treatment\ t$
- $Treats(t, d)$ $-$ $treatment\ t\ treats\ disease\ d$
- $TreatsSymptom(t, s)$ $-$ $treatment\ t\ improves\ symptom\ s$
- $Incompatible(t1, t2)$ $-$ $t1\ and\ t2\ must\ not\ be\ given\ together$
- $HighRisk(p)$ $-$ $p\ is\ a\ high-risk\ patient$
- $Age(p)$ $-$ $integer\ age\ for\ patient\ p$
- $Eligible(p, t)$ $-$ $t\ is\ suitable\ for\ p\ (to\ be\ derived)$
- $Contraindicated(p, t)$ $-$ $t\ should\ not\ be\ given\ to\ p\ (to\ be\ derived)$
- $Recommended(p, t)$ $-$ $t\ is\ part\ of\ the\ treatment\ plan\ for\ p$

3. FOL DEFINITIONS AND CONSTRAINTS

DEFINITION 1 – Eligible Treatment
English: A treatment is eligible for a patient if it treats at least one disease that the patient has and the patient is not allergic to it.
FOL Formula: ∀p ∀t (Eligible(p, t) ↔ (∃d (HasDisease(p, d) ∧ Treats(t, d)) ∧ ¬Allergic(p, t)))

DEFINITION 2 – Contraindicated Treatment
English: A treatment is contraindicated if the patient is allergic to it, or if there is a cross-allergy (if allergic to paracetamol then ibuprofen is contraindicated).
FOL Formula: $\forall p\ \forall t\ (Contraindicated(p, t) \leftrightarrow (Allergic(p, t) \vee (t = ibuprofen \wedge Allergic(p, paracetamol))))$

CONSTRAINT 3 – No Incompatible Pairs
English: If a treatment t1 is recommended to a patient and t1 is incompatible with t2, then t2 must not be recommended to that patient.
FOL Formula:
$\forall p\ \forall t1\ \forall t2\ (Recommended(p, t1) \wedge Incompatible(t1, t2) \rightarrow \neg Recommended(p, t2))$

CONSTRAINT 4 – Treat All Diseases
English: For every disease a patient has, at least one treatment that treats that disease must be recommended.
FOL Formula:
$\forall p\ \forall d\ (HasDisease(p, d) \rightarrow \exists t\ (Treats(t, d) \wedge Recommended(p, t)))$

CONSTRAINT 5 – Only Eligible Treatments
English: A treatment can only be recommended if it is eligible for the patient.
FOL Formula:
$\forall p\ \forall t\ (Recommended(p, t) \rightarrow Eligible(p, t))$

CONSTRAINT 6 – Limit Concurrent Treatments
English: No patient should receive more than 3 different treatments at the same time.
FOL Formula: $\forall p\ (\#\{t \mid Recommended(p, t)\} \leq 3)$

CONSTRAINT 9 – Single Treatment Per Disease
English: For each disease, a patient should not receive two different treatments that both treat the same disease.
FOL Formula:

$$\forall p\ \forall d\ \forall t1\ \forall t2\ (HasDisease(p,d)\ \wedge\ Treats(t1,d)\ \wedge\ Treats(t2,d)\ \wedge\ Recommended(p,t1)\ \wedge\ Recommended(p,t2)\ \rightarrow\ t1\ =\ t2)$$

CONSTRAINT 19 – Safety: No Contraindicated Treatments

English: A treatment that is contraindicated for a patient must never be recommended to that patient.

FOL Formula:

$$\forall p\ \forall t\ (Recommended(p,t)\ \rightarrow\ \neg Contraindicated(p,t))$$

4. ADDITIONAL CONSTRAINTS

CONSTRAINT 7 – High-Risk Symptom Requirement

English: If a patient is high-risk, every recommended treatment must address at least one symptom that the patient currently has.

FOL Formula:

$$\forall p\ (HighRisk(p)\ \rightarrow\ \forall t\ (Recommended(p,t)\ \rightarrow\ \exists s\ (HasSymptom(p,s)\ \wedge\ TreatsSymptom(t,s))))$$

CONSTRAINT 8 – Elderly Avoid NSAIDs

English: Patients older than 75 years must not be recommended ibuprofen.

FOL Formula:

$$\forall p\ (Age(p)\ >\ 75\ \rightarrow\ \neg Recommended(p,ibuprofen))$$

CONSTRAINT 11 – Multi-Condition Treatment

English: If a patient has both flu and pneumonia, antibiotics must be recommended.

FOL Formula:

$$\forall p\ (HasDisease(p,flu)\ \wedge\ HasDisease(p,pneumonia)\ \rightarrow\ Recommended(p,antibiotics))$$

CONSTRAINT 12 – Respiratory Priority

English: If a patient has asthma or pneumonia, a bronchodilator must be recommended.

FOL Formula:

$$\forall p\ ((HasDisease(p,asthma)\ \vee\ HasDisease(p,pneumonia))\ \rightarrow\ Recommended(p,bronchodilator))$$

CONSTRAINT 13 – Hypertension Control

English: Any patient with hypertension must be recommended amlodipine.

FOL Formula:

$$\forall p\ (HasDisease(p,hypertension)\ \rightarrow\ Recommended(p,amlodipine))$$

CONSTRAINT 14 – Selective Antibiotic Use

English: Patients without high-risk factors and without pneumonia should not receive antibiotics.

FOL Formula:

$$\forall p\ (\neg HighRisk(p)\ \wedge\ \neg HasDisease(p,pneumonia)\ \rightarrow\ \neg Recommended(p,antibiotics))$$

CONSTRAINT 16 – Elderly Medication Limits

English: Patients older than 70 years should receive at most 2 different treatments.

FOL Formula:

$$\forall p\ (Age(p)\ >\ 70\ \rightarrow\ \#\{t\mid Recommended(p,t)\}\ \leq\ 2)$$

5. HOW THE SYSTEM WORKS

We implemented these definitions and constraints in IDP and tested the system with four example patients: Alice (35, has flu), Bob (72, has pneumonia), Charlie (28, has asthma), and Diana (80, high-risk, has hypertension and flu).

When we run the IDP model and ask for all models with allmodels(T, S), the system finds treatment plans that satisfy every single constraint. For example:

- Alice with flu receives paracetamol (treats flu, not contraindicated).
- Bob with pneumonia receives antibiotics and bronchodilator (treats pneumonia and helps breathing).
- Charlie with asthma receives bronchodilator (treats asthma, not contraindicated).
- Diana (high-risk, elderly, with hypertension and flu) receives amlodipine (for hypertension) and other treatments that relieve her symptoms, but never ibuprofen (elderly restriction) or unnecessary antibiotics (low-risk rule does not apply because she is high-risk).

The FOL definitions and constraints work together to ensure the recommendations are medically sound, safe, and respect all the rules. If the medical knowledge changes, we can update the constraints and re-run the model to see how recommendations change.

6. CONCLUSION

This project showed step by step how we can turn an informal description of a healthcare recommendation problem into a precise logical model and an executable expert system. We started from English rules about diseases, treatments, allergies and risk factors, translated them into FOL, and then encoded them in IDP so that the system can actually compute treatment plans. The final theory enforces that every disease is treated, that allergies and drug incompatibilities are respected, and that special groups like high-risk or elderly patients are handled more carefully.

Working on the project also made the strengths of logic-based modelling very clear. Because all assumptions are written as explicit formulas, it is easy to understand and explain why a certain patient gets a certain treatment, or why another treatment is forbidden. If some medical guideline changes, we do not have to rewrite complex code; we can simply update or add a constraint and re-run the solver. In this way the project fulfilled the goals of the course document: we practiced natural language to FOL translation, we used an automated reasoning system (IDP), and we learned how to design and analyse a small but realistic expert system in a principled way.