CSE 505
Computing with Logic

Project Presentation

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A Physician Advisory System for Chronic Heart Failure management based on knowledge patterns

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Introduction

Management of chronic diseases such as chronic heart failure (CHF) is a major problem in health care. A standard approach followed by the medical community is to have a committee of experts develop guidelines that all physicians should follow. These guidelines typically consist of a series of complex rules that make recommendations based on a patient's information. Due to their complexity, often the guidelines are ignored or not complied with at all. It is not even clear whether it is humanly possible to follow these guidelines due to their length and complexity.

Guidelines

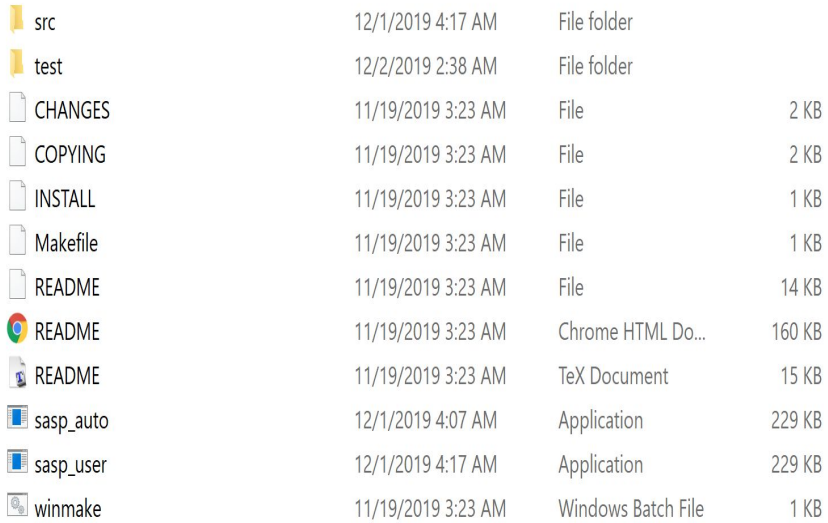
Physician Advisory System

Image Credit: Photographee.eu - Fotolia

s(ASP)

s(ASP) is an implementation of the stable model semantics of logic programming i.e., logic programs extended with negation, in the presence of predicates with arbitrary terms. Such programs need not have a finite grounding, so traditional methods do not apply.

Using this method, a normal logic program with predicates can be executed directly under the stable model semantics without requiring it to be grounded either before or during execution and without requiring that its variables range over a finite domain.



src	12/1/2019 4:17 AM	File folder	
test	12/2/2019 2:38 AM	File folder	
CHANGES	11/19/2019 3:23 AM	File	2 KB
COPYING	11/19/2019 3:23 AM	File	2 KB
INSTALL	11/19/2019 3:23 AM	File	1 KB
Makefile	11/19/2019 3:23 AM	File	1 KB
README	11/19/2019 3:23 AM	File	14 KB
README	11/19/2019 3:23 AM	Chrome HTML Do...	160 KB
README	11/19/2019 3:23 AM	TeX Document	15 KB
sasp_auto	12/1/2019 4:07 AM	Application	229 KB
sasp_user	12/1/2019 4:17 AM	Application	229 KB
winmake	11/19/2019 3:23 AM	Windows Batch File	1 KB

s(ASP)

Reference:
MARPLE, K., SALAZAR, E. AND GUPTA, G. 2016. s(ASP)
https://sourceforge.net/projects/saspsystem/

Steps:

1. Building s(ASP) requires **SWI Prolog** to be installed on the local machine.

2. Compile s(ASP) to generate an executable file. Locate src/folder and enter the following command:
   swipl -L0 -G0 -T0 --goal=main --stand_alone=true -o sasp -c main.pl

3. Write Program with Rules and Facts.

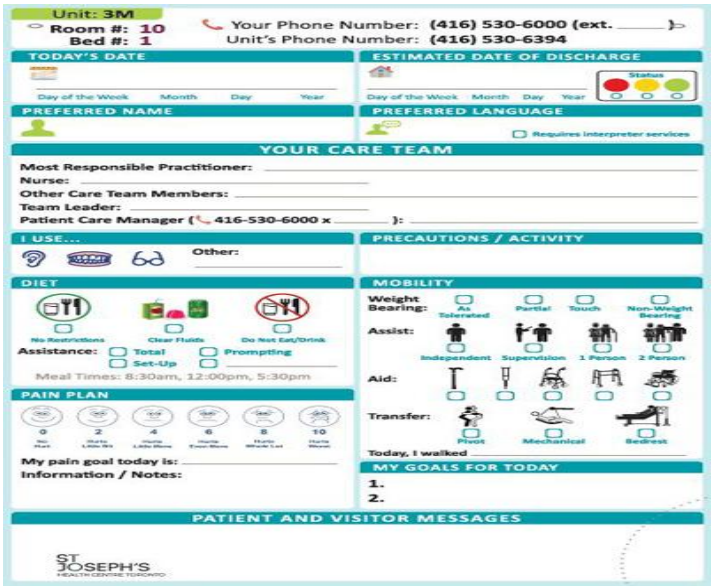
4. Run Program: ***sasp -i advisory_system.lp***

Components of the Physician Advisory System

Rule Database

Guidelines

Fact Table



Patient Information

Image Credit: Creator: Andrew Milligan

Objective - Create Rule Database

In this paper we describe a physician-advisory system for CHF management that codes the entire set of clinical practice guidelines for CHF using answer set programming (ASP). Our approach is based on developing reasoning templates, that we call knowledge patterns, and using them to systemically code the clinical guidelines for CHF as ASP rules.

Guidelines

ASP

Using s(ASP) System

Physician Advisory System

Image Credit: Photographee.eu - Fotolia

Reasoning Templates - Knowledge Patterns

The ACCF/AHA guidelines are written in English and are quite complex. Our task was to code these guidelines in ASP.

To simplify this task, reasoning templates were developed, that were called knowledge patterns. These knowledge patterns are quite general and serve as solid building blocks for systematically translating the specifications written in English to ASP.

Note certain facts:

- Multiple rules can lead to the recommendation of the same treatment.
- Multiple rules can lead to contraindication of a treatment.
- A treatment cannot be recommended if at least one contraindication for that treatment is present.
- A given treatment recommendation can impact the recommendation and/or contraindication of other treatments.

Reasoning Templates - Knowledge Patterns

1. Aggressive Reasoning

- Take an action (e.g., recommend treatment) if there is a reason.
- No evidence of danger means there is no danger in taking that action.

```
recommendation(Choice) :- preconditions(Choice),
    not contraindication(Choice).
contraindication(Choice) :- dangers(Choice).
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "Digoxin can be beneficial in patients with HFrEF, unless
contraindicated, to decrease hospitalizations for HF."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

recommendation(digoxin, class_2a) :-
    not contraindication(digoxin),
    accf_stage(c), hf_with_reduced_ef.
contraindication(digoxin) :-
    evidence(atrioventricular_block).
```

Example

Reasoning Templates - Knowledge Patterns

2. Conservative Reasoning

- A reason for a recommendation is not enough.
- Evidence that the recommendation is not harmful must be available.

```
recommendation(Choice) :- preconditions(Choice),
    not contraindication(Choice).
contraindication(Choice) :- not -dangers(Choice).
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "In patients with structural cardiac abnormalities,
including LV hypertrophy, in the absence of a history of MI or ACS,
blood pressure should be controlled in accordance with clinical
practice guidelines for hypertension to prevent symptomatic HF."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

recommendation(blood_pressure_control, class_1):-
    accf_stage(b),
    diagnosis(structural_cardiac_abnormalities),
    not contraindication(blood_pressure_control).
contraindication(blood_pressure_control):- not -history(mi).
contraindication(blood_pressure_control):- not -history(acs).
```

Example

Reasoning Templates - Knowledge Patterns

3. Anti-Recommendation

- A choice can be prohibited if evidence of danger can be found.

```
contraindication(choice) :- dangers(Choice).
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "Anticoagulation is not recommended in patients with
chronic HFrEF without AF, a prior thromboembolic event,
or a cardioembolic source."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

contraindication(anticoagulation) :-
    not cardioembolic_source,
    not diagnosis(af),
    not history(thromboembolism),
    hf_with_reduced_ef.
```

Example

Reasoning Templates - Knowledge Patterns

4. Preference

- Use the second-line choice when the first-line choice is not available.

```
recommendation(First_choice) :- conditions_for_both_choices,
    not contraindication(First_choice).
recommendation(Second_choice) :- conditions_for_both_choices,
    contraindication(First_choice),
    not contraindication(Second_choice).
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "ARBs are recommended in patients with HFrEF with current
or prior symptoms who are ACE inhibitor intolerant, unless
contraindicated, to reduce morbidity and mortality."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

recommendation(ace_inhibitors, class_1) :-
    not contraindication(ace_inhibitors),
    accf_stage(c), hf_with_reduced_ef.
recommendation(arbs, class_1) :-
    contraindication(ace_inhibitors),
    not contraindication(arbs),
    not taboo_choice(arbs),
    accf_stage(c),
    hf_with_reduced_ef.
```

Example

Reasoning Templates - Knowledge Patterns

5. Concomitant Choice

- If a choice is made, some other choices are automatically in effect unless they are prohibited.

```
recommendation(Trigger_choice) :- preconditions(Trigger_choice),
    not contraindication(Trigger_choice),
    not skip_concomitant_choice(Trigger_choice).
skip_concomitant_choice(Trigger_choice) :-
    not recommendation(Concomitant_choice),
    not contraindication(Concomitant_choice).
recommendation(Concomitant_choice) :-
    recommendation(Trigger_choice),
    not contraindication(Concomitant_choice).
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "Diuretics should generally be combined with an ACE inhib-
itor, beta blocker, and aldosterone antagonist. Few patients with HF
will be able to maintain target weight without the use of diuretics."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

recommendation(ace_inhibitors, class_1) :-
    accf_stage(c),
    not skip_concomitant_choice(ace_inhibitors),
    not contraindication(ace_inhibitors),
    hf_with_reduced_ef.
skip_concomitant_treatment(ace_inhibitors) :-
    hf_with_reduced_ef,
    not recommendation(diuretics, class_1),
    not contraindication(diuretics).
recommendation(diuretics, class_1) :-
    hf_with_reduced_ef,
    not contraindication(diuretics),
    recommendation(ace_inhibitors, class_1).
```

Example

Reasoning Templates - Knowledge Patterns

6. Indispensable Choice

- If a choice is made, some other choices must also be made.
- If those choices can't be made, then the first choice is revoked.
- Note: Choosing "Trigger choice" forces "Indispensable choice.

```
recommendation(beta_blockers, class_1) :-
    not skip_concomitant_choice(beta_blockers),
    not absent_indispensable_choice(beta_blockers),
    not contraindication(beta_blockers), accf_stage(c), hf_with_reduced_ef.
absent_indispensable_choice(beta_blockers) :-
    not recommendation(diuretics, class_1), hf_with_reduced_ef,
    accf_stage(c), current_or_recent_history_of_fluid_retention.
recommendation(diuretics, class_1) :-
    recommendation(beta_blockers, class_1),
    not contraindication(diuretics), accf_stage(c), hf_with_reduced_ef,
    current_or_recent_history_of_fluid_retention.
```

Template

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "In patients with a current or recent history of fluid
retention, beta blockers should not be prescribed without diuretics."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

recommendation(beta_blockers, class_1) :-
    not skip_concomitant_choice(beta_blockers),
    not absent_indispensable_choice(beta_blockers),
    not contraindication(beta_blockers),
    accf_stage(c),
    hf_with_reduced_ef.
absent_indispensable_choice(beta_blockers) :-
    not recommendation(diuretics, class_1),
    hf_with_reduced_ef,
    accf_stage(c),
    current_or_recent_history_of_fluid_retention.
recommendation(diuretics, class_1) :-
    recommendation(beta_blockers, class_1),
    not contraindication(diuretics),
    accf_stage(c),
    hf_with_reduced_ef,
    current_or_recent_history_of_fluid_retention.
```

Example

Reasoning Templates - Knowledge Patterns

7. Incompatible Choice

- Some choices cannot be in effect at the same time.

```
taboo_choice(Choice_1) :-
    recommendation(Choice_2),
    ...,
    recommendation(Choice_n).
taboo_choice(Choice_2) :-
    recommendation(Choice_1),
    recommendation(Choice_3),
    ....
    recommendation(Choice_n).
    ...
taboo_choice(Choice_n) :-
    recommendation(Choice_1),
    recommendation(Choice_2),
    ....
    recommendation(Choice_n-1).
```

```
recommendation(Choice_1) :-
    conditions_for_choice_1,
    not contraindication(Choice_1),
    not taboo_choice(Choice_1).
recommendation(Choice_2) :-
    conditions_for_choice_2,
    not contraindication(Choice_2),
    not taboo_choice(Choice_2).

    ...
recommendation(Choice_n) :-
    conditions_for_choice_n,
    not contraindication(Choice_n),
    not taboo_choice(Choice_n).
```

Template

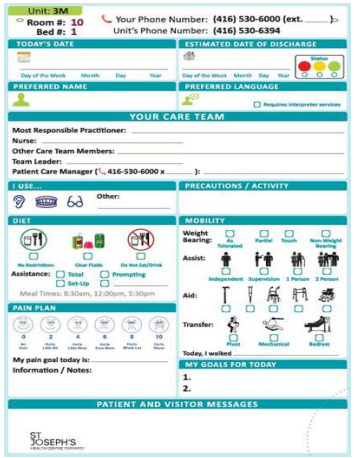
```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Guideline: "Routine combined use of an ACE inhibitor, ARB, and
aldosterone antagonist is potentially harmful for patients with HFrEF."
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

taboo_choice(ace_inhibitors) :-
    hf_with_reduced_ef,
    recommendation(arbs, class_1),
    recommendation(aldosterone_antagonist, class_1).
taboo_choice(arbs) :-
    hf_with_reduced_ef,
    recommendation(ace_inhibitors, class_1),
    recommendation(aldosterone_antagonist, class_1).
taboo_choice(aldosterone_antagonist) :-
    hf_with_reduced_ef,
    recommendation(arbs, class_1),
    recommendation(ace_inhibitors, class_1).
recommendation(ace_inhibitors, class_1) :-
    accf_stage(c),
    hf_with_reduced_ef,
    not skip_concomitant_choice(ace_inhibitors),
    not taboo_choice(ace_inhibitors),
    not contraindication(ace_inhibitors).
recommendation(arbs, class_1) :-
    contraindication(ace_inhibitors),
    not contraindication(arbs),
    not taboo_choice(arbs),
    accf_stage(c),
    hf_with_reduced_ef.
recommendation(aldosterone_antagonist, class_1) :-
    conditions_for_aldosterone_antagonist_class_1,
    not skip_concomitant_choice(aldosterone_antagonist),
    not contraindication(aldosterone_antagonist),
    not taboo_choice(aldosterone_antagonist).
```

Example

Objective - Generate Fact Table

Given a patient's medical information, our system generates a recommendation for treatment just as a human physician would, using the guidelines.



Patient Information

Physician Advisory System

Recommendation

Image Credit: Creator: Andrew Milligan

Patient Information as Input

Demographics	Gender; age; race
Measurements	Weight; creatinine; potassium; sinus rhythm; left bundle branch block; non-left bundle branch block; QRS duration; ejection fraction NYHA class; ACCF/AHA stage;
Diseases and Symptoms	Sleep apnea, acute coronary syndrome; myocardial infarction; obesity; diabetes; stroke; fluid retention; angioedema; ischemic attack; thromboembolism; elevated plasma natriuretic peptide level; asymptomatic ischemic cardiomyopathy; lipid disorders; hypertension; atrial fibrillation; myocardial ischemia; coronary artery disease; dilated cardiomyopathy; acute profound hemodynamic compromise; threatened end organ dysfunction; ischemic heart disease;angina; structural cardiac abnormalities; atrioventricular block; volume overload
Miscellany	Expectation of survival;pregnancy; history of cardiovascular hospitalization; history of standard neurohumoral antagonist therapy; risk of cardioembolic stroke; eligibility of significant ventricular pacing; eligibility of mechanical circulatory support; dependence of continuous parenteral inotropic; ischemic etiology of HF; requirement of ventricular pacing

Patient Information as Input

```
% Doctor's Assesement
accf_stage(c).
nyha_class(3).
expectation_of_survival(3).

% Demographics of the patient
gender(female).
age(78).

% Measurements from the Lab
hf_with_reduced_ef.
measurement(creatinine, 1.8).
measurement(potassium, 4.9).
measurement(lvef, 0.35).
measurement(lbbb, 180).
measurement(sinus_rhythm).
```

```
% History of the Patient
diagnosis(myocardial_ischemia).
diagnosis(atrial_fibrillation).
diagnosis(coronary_artery_disease).
diagonosis(hypertension).
evidence(ischemic_etiology_of_hf).
evidence(sleep_apnea).
evidence(fluid_retention).
history(mi, recent).
history(stroke).
history(cardiovascular_hospitalization).
post_mi(40).
```

Obtain Recommendation as Output

Run the following query to get recommendations:
recommendation(Treatment, Class).

Each treatment recommendation (represented as a partial answer set) contains all of the predicates that must hold in order for the query to be successful.

1. **Interactive Query**

```
C:\Users\melta\Desktop\SBU\Fall 2019\CSE 505 - CwL\Project\sasp-1.1.0\sasp-1.1.0\test>sasp_user -i advisory_system.lp
?- recommendation(Treatment,Class).
{ accf_stage(c), hf_with_reduced_ef, recommendation(ace_inhibitors,class_1), recommendation(digoxin,class_2a), not -hist
ory(Var19), not conditions_for_aldosterone_antagonist_class_1, not contraindication(ace_inhibitors), not contraindicatio
n(digoxin), not evidence(atrioventricular_block), not recommendation(aldosterone_antagonist,class_1), not recommendation
(arbs,class_1) }
Treatment = digoxin,
Class = class_2a
```

Obtain Recommendation as Output

Run the following query to get recommendations:
recommendation(Treatment, Class).

Each treatment recommendation (represented as a partial answer set) contains all of the predicates that must hold in order for the query to be successful.

2. Auto Query

```
#compute 3 {recommendation(Treatment,Class)}.
```

```
C:\Users\melta\Desktop\SBU\Fall 2019\CSE 505 - CwL\Project\sasp-1.1.0\sasp-1.1.0\test>sasp_auto -i advisory_system.lp
{ accf_stage(c), hf_with_reduced_ef, recommendation(ace_inhibitors,class_1), recommendation(digoxin,class_2a), not -hist
ory(Var19), not conditions_for_aldosterone_antagonist_class_1, not contraindication(ace_inhibitors), not contraindicati
n(digoxin), not evidence(atrioventricular_block), not recommendation(aldosterone_antagonist,class_1), not recommendatio
(arbs,class_1) }
Treatment = digoxin,
Class = class_2a
```