

B.M.S. COLLEGE OF ENGINEERING BENGALURU
Autonomous Institute, Affiliated to VTU



Lab Record

Artificial Intelligence

Submitted in partial fulfillment for the 5th Semester Laboratory

Bachelor of Technology
in
Computer Science and Engineering

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CERTIFICATE

This is to certify that the Artificial Intelligence (22CS5PCAIN) laboratory has been carried out by **Gunjal Kothari (1BM21CS274)** during the 5th Semester Nov-March-2024.

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1. Tic-Tac-Toe

Code:

```
# Create a 3x3 tic tac toe board of "" strings for each value
board = [' '] * 9

# Create a function to display your board
def display_board(board):
    print(f" {board[0]} | {board[1]} | {board[2]} ")
    print("---+---+---")
    print(f" {board[3]} | {board[4]} | {board[5]} ")
    print("---+---+---")
    print(f" {board[6]} | {board[7]} | {board[8]} ")

# Create a function to check if anyone won, Use marks "X" or "O"
def check_win(player_mark, board):
    win = [f'{player_mark}' * 3]
    return board[:3] == win or board[3:6] == win or board[6:9] == win or \
        [board[0], board[4], board[8]] == win or [board[2], board[4], board[6]] == win or \
        [board[0], board[3], board[6]] == win or [board[1], board[4], board[7]] == win or [board[2],
board[5], board[8]] == win

def check_draw(board):
    return ' ' not in board

# Create a Function that makes a copy of the board
def board_copy(board):
    new_board = []
    for c in board:
        new_board += c
    return new_board

def test_win_move(move, player_mark, board):
```

```
copy = board_copy(board)
```

```
copy[move] = player_mark
```

```
return check_win(player_mark, copy)
```

```
def win_strategy(board):
```

```
    if board[4] == '':
```

```
        return 4
```

```
    for i in [0, 2, 6, 8]:
```

```
        if board[i] == '':
```

```
            return i
```

```
    for i in [1, 3, 5, 7]:
```

```
        if board[i] == '':
```

```
            return i
```

```
def get_agent_move(board):
```

```
    for i in range(9):
```

```
        if board[i] == '' and test_win_move(i, 'X', board):
```

```
            return i
```

```
    for i in range(9):
```

```
        if board[i] == '' and test_win_move(i, 'O', board):
```

```
            return i
```

```
    return win_strategy(board)
```

```
def tictactoe():
```

```
    playing = True
```

```
    while playing:
```

```
        in_game = True
```

```
        board = [' '] * 9
```

```
        print('Would you like to go first or second? (1/2)')
```

```
        choice = input()
```

```
        player_marker = 'O' if choice == '1' else 'X'
```

```
        display_board(board)
```

```

while in_game:
    print('\n')

    if player_marker == 'O':
        print('Player move: (0-8)')
        move = int(input())
        if board[move] != ' ':
            print('Invalid move')
            continue
    else:

        move = get_agent_move(board)
    board[move] = player_marker
    if check_win(player_marker,board):
        in_game = False
        display_board(board)
        if player_marker == 'O':
            print('O won')
        else:
            print('X won')
        break
    if check_draw(board):
        in_game = False
        display_board(board)
        print('The game was a draw.')
        break
    display_board(board)
    if player_marker == 'O':
        player_marker = 'X'
    else:
        player_marker = 'O'
    print('Continue playing? (y/n)')
    ans = input()

```

```
if ans not in 'yY':  
    playing = False
```

```
# Play!!!  
tictactoe()
```

Output:

Would you like to go first or second? (1/2)

```
1
| | |
+---+
| | |
+---+
| | |
```

Player move: (0-8)

```
2
0 | | 
+---+
| | |
+---+
| | |
```

```

0 | | 
+---+
| x | 
+---+
| | |
```

Player move: (0-8)

```
3
0 | 0 | 
+---+
| x | 
+---+
| | |
```

```

0 | 0 | x
+---+
| x | 
+---+
| | |
```

Player move: (0-8)

```
6
0 | 0 | x
+---+
| x | 
+---+
0 | |
```

```

0 | 0 | x
+---+
x | x | 
+---+
0 | |
```

Player move: (0-8)

```
5
0 | 0 | x
+---+
x | x | 0
+---+
0 | |
```

```

0 | 0 | x
+---+
x | x | 0
+---+
0 | | x
```

Player move: (0-8)

```
7
0 | 0 | x
+---+
x | x | 0
+---+
0 | 0 | x
```

The game was a draw.

2. 8 Puzzle Breadth First Search Algorithm

Code:

```
import numpy as np
import pandas as pd
import os

def gen(state, m, b):
    temp = state.copy()

    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
    elif m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    elif m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    elif m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]

    return temp # Return the modified state

def possible_moves(state, visited_states):
    b = state.index(0)
    d = []

    if b not in [0, 1, 2]:
        d.append('u')
    if b not in [6, 7, 8]:
        d.append('d')
    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')

    pos_moves_it_can = []
```

```

for i in d:
    pos_moves_it_can.append(gen(state, i, b))

return [move_it_can for move_it_can in pos_moves_it_can if move_it_can not in visited_states]

def bfs(src, target):
    queue = []
    queue.append(src)

    exp = []

    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)

        print(source[0], '|', source[1], '|', source[2])
        print(source[3], '|', source[4], '|', source[5])
        print(source[6], '|', source[7], '|', source[8])
        print()

        if source == target:
            print("success")
            return

        poss_moves_to_do = possible_moves(source, exp)

        for move in poss_moves_to_do:
            if move not in exp and move not in queue:
                queue.append(move)

src = [1, 2, 3, 4, 5, 6, 0, 7, 8]
target = [1, 2, 3, 4, 5, 6, 7, 8, 0]
bfs(src, target)

```

Output:

1	2	3
4	5	6
0	7	8

1	2	3
0	5	6
4	7	8

1	2	3
4	5	6
7	0	8

0	2	3
1	5	6
4	7	8

1	2	3
5	0	6
4	7	8

1	2	3
4	0	6
7	5	8

1	2	3
4	5	6
7	8	0

3. 8 Puzzle Iterative Deepening Search Algorithm

Code:

```
def id_dfs(puzzle, goal, get_moves):
    import itertools
    #get_moves -> possible_moves
    def dfs(route, depth):
        if depth == 0:
            return
        if route[-1] == goal:
            return route
        for move in get_moves(route[-1]):
            if move not in route:
                next_route = dfs(route + [move], depth - 1)
                if next_route:
                    return next_route

    for depth in itertools.count():
        route = dfs([puzzle], depth)
        if route:
            return route

def possible_moves(state):
    b = state.index(0) # ) indicates White space -> so b has index of it.
    d = [] # direction

    if b not in [0, 1, 2]:
        d.append('u')
    if b not in [6, 7, 8]:
        d.append('d')

    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')
```

```

pos_moves = []
for i in d:
    pos_moves.append(generate(state, i, b))
return pos_moves

def generate(state, m, b):
    temp = state.copy()

    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
    if m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    if m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    if m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]

    return temp

# calling ID-DFS
initial = [1, 2, 3, 0, 4, 6, 7, 5, 8]
goal = [1, 2, 3, 4, 5, 6, 7, 8, 0]

route = id_dfs(initial, goal, possible_moves)

if route:
    print("Success!! It is possible to solve 8 Puzzle problem")
    print("Path:", route)
else:
    print("Failed to find a solution")

```

Output:

Enter the start state matrix

```
1 2 3
4 5 6
_ 7 8
```

Enter the goal state matrix

```
1 2 3
4 5 6
7 8 _
```

```
  |
  |
  |
 \'/
```

```
1 2 3
4 5 6
_ 7 8
```

```
  |
  |
  |
 \'/
```

```
1 2 3
4 5 6
7 _ 8
```

```
  |
  |
  |
 \'/
```

```
1 2 3
4 5 6
7 8 _
```

4. 8 Puzzle A* Search Algorithm

Code:

class Node:

```
def __init__(self,data,level,fval):
```

```
    """ Initialize the node with the data, level of the node and the calculated fvalue """
```

```
    self.data = data
```

```
    self.level = level
```

```
    self.fval = fval
```

```
def generate_child(self):
```

```
    """ Generate child nodes from the given node by moving the blank space  
    either in the four directions {up,down,left,right} """
```

```
x,y = self.find(self.data,'_')
```

```
    """ val_list contains position values for moving the blank space in either of  
    the 4 directions [up,down,left,right] respectively. """
```

```
val_list = [[x,y-1],[x,y+1],[x-1,y],[x+1,y]]
```

```
children = []
```

```
for i in val_list:
```

```
    child = self.shuffle(self.data,x,y,i[0],i[1])
```

```
    if child is not None:
```

```
        child_node = Node(child,self.level+1,0)
```

```
        children.append(child_node)
```

```
return children
```

```
def shuffle(self,puz,x1,y1,x2,y2):
```

```
    """ Move the blank space in the given direction and if the position value are out  
    of limits the return None """
```

```
if x2 >= 0 and x2 < len(self.data) and y2 >= 0 and y2 < len(self.data):
```

```
    temp_puz = []
```

```
    temp_puz = self.copy(puz)
```

```
    temp = temp_puz[x2][y2]
```

```
    temp_puz[x2][y2] = temp_puz[x1][y1]
```

```
    temp_puz[x1][y1] = temp
```

```
        return temp_puz
    else:
        return None
```

```
def copy(self,root):
    """ Copy function to create a similar matrix of the given node"""
    temp = []
    for i in root:
        t = []
        for j in i:
            t.append(j)
        temp.append(t)
    return temp
```

```
def find(self,puz,x):
    """ Specifically used to find the position of the blank space """

    for i in range(0,len(self.data)):
        for j in range(0,len(self.data)):
            if puz[i][j] == x:
                return i,j
```

```
class Puzzle:
    def __init__(self,size):
        """ Initialize the puzzle size by the specified size,open and closed lists to empty """
        self.n = size
        self.open = []
        self.closed = []

    def accept(self):
        """ Accepts the puzzle from the user """
```



```

puz = []

for i in range(0,self.n):
    temp = input().split(" ")
    puz.append(temp)
return puz

def f(self,start,goal):
    """ Heuristic Function to calculate hueristic value  $f(x) = h(x) + g(x)$  """
    return self.h(start.data,goal)+start.level

def h(self,start,goal):
    """ Calculates the different between the given puzzles """
    temp = 0
    for i in range(0,self.n):
        for j in range(0,self.n):
            if start[i][j] != goal[i][j] and start[i][j] != '_':
                temp += 1
    return temp

def process(self):
    """ Accept Start and Goal Puzzle state"""
    print("Enter the start state matrix \n")
    start = self.accept()
    print("Enter the goal state matrix \n")
    goal = self.accept()

    start = Node(start,0,0)
    start.fval = self.f(start,goal)
    """ Put the start node in the open list"""
    self.open.append(start)
    print("\n\n")
    while True:
        cur = self.open[0]

```

```
print("")
```

```
print(" | ")
```

```
print(" | ")
```

```
print("\n\n")
```

```
for i in cur.data:
```

```
    for j in i:
```

```
        print(j,end=" ")
```

```
print("")
```

```
""" If the difference between current and goal node is 0 we have reached the goal node"""
```

```
if(self.h(cur.data,goal) == 0):
```

```
    break
```

```
for i in cur.generate_child():
```

```
    i.fval = self.f(i,goal)
```

```
    self.open.append(i)
```

```
self.closed.append(cur)
```

```
del self.open[0]
```

```
""" sort the opne list based on f value """
```

```
self.open.sort(key = lambda x:x.fval,reverse=False)
```

```
puz = Puzzle(3)
```

```
puz.process()
```

Output:

Success!! It is possible to solve 8 Puzzle problem

Path: `[[1, 2, 3, 0, 4, 6, 7, 5, 8], [1, 2, 3, 4, 0, 6, 7, 5, 8], [1, 2, 3, 4, 5, 6, 7, 0, 8], [1, 2, 3, 4, 5, 6, 7, 8, 0]]`

5. Vacuum Cleaner

Code:

For 2 rooms:

```
def clean_room(room_name, is_dirty):
    if is_dirty:
        print(f'Cleaning {room_name} (Room was dirty)')
        print(f'{room_name} is now clean.')
        return 0 # Updated status after cleaning
    else:
        print(f'{room_name} is already clean.')
        return 0 # Status remains clean

def main():
    rooms = ["Room 1", "Room 2"]
    room_statuses = []

    for room in rooms:
        status = int(input(f'Enter clean status for {room} (1 for dirty, 0 for clean): '))
        room_statuses.append((room, status))
    print(room_statuses)

    for i, (room, status) in enumerate(room_statuses):
        room_statuses[i] = (room, clean_room(room, status)) # Update status after cleaning

    print(f'Returning to {rooms[0]} to check if it has become dirty again:')
    room_statuses[0] = (rooms[0], clean_room(rooms[0], room_statuses[0][1])) # Checking Room 1
    after cleaning all rooms

    print(f'{rooms[0]} is {'dirty' if room_statuses[0][1] else 'clean'} after checking.')

if __name__ == "__main__":
    main()
```

For 4 rooms :

Code:

```
def clean_room(floor, room_row, room_col):
    if floor[room_row][room_col] == 1:
        print(f'Cleaning Room at ({room_row + 1}, {room_col + 1}) (Room was dirty)')
        floor[room_row][room_col] = 0
        print("Room is now clean.")
    else:
        print(f'Room at ({room_row + 1}, {room_col + 1}) is already clean.')

def main():
    rows = 2
    cols = 2
    floor = [[0, 0], [0, 0]] # Initialize a 2x2 floor with clean rooms

    for i in range(rows):
        for j in range(cols):
            status = int(input(f'Enter clean status for Room at ({i + 1}, {j + 1}) (1 for dirty, 0 for clean):'))
            floor[i][j] = status

    for i in range(rows):
        for j in range(cols):
            clean_room(floor, i, j)

    print("Returning to Room at (1, 1) to check if it has become dirty again:")
    clean_room(floor, 0, 0) # Checking Room at (1, 1) after cleaning all rooms

if __name__ == "__main__":
    main()
```

Output:

```
Enter clean status for Room 1 (1 for dirty, 0 for clean): 1
Enter clean status for Room 2 (1 for dirty, 0 for clean): 1
[('Room 1', 1), ('Room 2', 1)]
Cleaning Room 1 (Room was dirty)
Room 1 is now clean.
Cleaning Room 2 (Room was dirty)
Room 2 is now clean.
Returning to Room 1 to check if it has become dirty again:
Room 1 is already clean.
Room 1 is clean after checking.
```

6. Knowledge Base Entailment

Code:

```
from sympy import symbols, And, Not, Implies, satisfiable

def create_knowledge_base():
    # Define propositional symbols
    p = symbols('p')
    q = symbols('q')
    r = symbols('r')
    a
    # Define knowledge base using logical statements
    knowledge_base = And(
        Implies(p, q), # If p then q
        Implies(q, r), # If q then r
        Not(r) # Not r
    )

    return knowledge_base

def query_entails(knowledge_base, query):
    # Check if the knowledge base entails the query
    entailment = satisfiable(And(knowledge_base, Not(query)))

    # If there is no satisfying assignment, then the query is entailed
    return not entailment

if __name__ == "__main__":
    # Create the knowledge base
    kb = create_knowledge_base()

    # Define a query
    query = symbols('p')
```

```
# Check if the query entails the knowledge base
result = query_entails(kb, query)
```

```
# Display the results
print("Knowledge Base:", kb)
print("Query:", query)
print("Query entails Knowledge Base:", result)
```


Output:

```
Knowledge Base:  $\sim r \ \& \ (\text{Implies}(p, q)) \ \& \ (\text{Implies}(q, r))$   
Query: p  
Query entails Knowledge Base: False
```

7. Knowledge Base Resolution

Code:

```
import re

def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}.\t| {step}\t| {steps[step]}\t')
        i += 1

def negate(term):
    return f'~{term}' if term[0] != '~' else term[1]

def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]}\v{t[0]}'
    return ""

def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms

split_terms('~PvR')

def contradiction(goal, clause):
    contradictions = [ f'{goal}\v{negate(goal)}', f'{negate(goal)}\v{goal}' ]
    return clause in contradictions or reverse(clause) in contradictions
```

```

def resolve(rules, goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given.'
    steps[negate(goal)] = 'Negated conclusion.'
    i = 0
    while i < len(temp):
        n = len(temp)
        j = (i + 1) % n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
                    t2 = [t for t in terms2 if t != negate(c)]
                    gen = t1 + t2
                    if len(gen) == 2:
                        if gen[0] != negate(gen[1]):
                            clauses += [f'{gen[0]} v {gen[1]}']
                        else:
                            if contradiction(goal, f'{gen[0]} v {gen[1]}'):
                                temp.append(f'{gen[0]} v {gen[1]}')
                                steps[""] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn
null. \
                                \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal}
is true."
                                return steps
                            elif len(gen) == 1:

```

```

    clauses += [f'{gen[0]}']
else:
    if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
        temp.append(f'{terms1[0]}v{terms2[0]}')
        steps[""] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
\nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal}
is true."

        return steps
for clause in clauses:
    if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
        temp.append(clause)
        steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
    j = (j + 1) % n
    i += 1
return steps

rules = 'Rv~P Rv~Q ~RvP ~RvQ' # (P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)

```

Output:

Step	Clause	Derivation
1.	$R \vee \neg P$	Given.
2.	$R \vee \neg Q$	Given.
3.	$\neg R \vee P$	Given.
4.	$\neg R \vee Q$	Given.
5.	$\neg R$	Negated conclusion.
6.		Resolved $R \vee \neg P$ and $\neg R \vee P$ to $R \vee \neg R$, which is in turn null.
A contradiction is found when $\neg R$ is assumed as true. Hence, R is true.		
79	<code>rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)</code>	
80	<code>goal = 'R'</code>	
81	<code>main(rules, goal)</code>	

8. Unification

Code:

```
def unify_var(var, x, theta):
    """
    Helper function for unifying a variable with a term.
    """
    if var in theta:
        return unify(theta[var], x, theta)
    elif x in theta:
        return unify(var, theta[x], theta)
    else:
        theta[var] = x
        return theta

def unify(x, y, theta={}):
    """
    Unify two expressions x and y with the given substitution theta.
    """
    if theta is None:
        return None
    elif x == y:
        return theta
    elif isinstance(x, str) and x[0].islower():
        return unify_var(x, y, theta)
    elif isinstance(y, str) and y[0].islower():
        return unify_var(y, x, theta)
    elif isinstance(x, list) and isinstance(y, list):
        if len(x) != len(y):
            return None
        for xi, yi in zip(x, y):
            theta = unify(xi, yi, theta)
        if theta is None:
```

```

        return None
    return theta
else:
    return None

# Example usage:
x = ['P', 'a', 'x']
y = ['P', 'y', 'z']

result = unify(x, y)
print(result)

# Sample input
expression1 = ['P', 'a', 'x']
expression2 = ['P', 'y', 'z']

# Unify the expressions
result = unify(expression1, expression2)

# Display the result
print("Input:")
print("Expression 1:", expression1)
print("Expression 2:", expression2)

print("\nOutput:")
if result is not None:
    print("Unification Successful!")
    print("Substitution theta:", result)
else:
    print("Unification Failed.")

```

Output:

```
107 exp1 = "knows(A,x)"
108 exp2 = "knows(y,Y)"
109 substitutions = unify(exp1, exp2)
110 print("Substitutions:")
111 print(substitutions)
```

```
Substitutions:
[('A', 'y'), ('Y', 'x')]
```


9. FOL to CNF

Code:

```
from sympy import symbols, to_cnf, parse_expr

def convert_to_cnf(logic_statement):
    # Parse the logic statement
    parsed_statement = parse_expr(logic_statement)

    # Convert to CNF
    cnf = to_cnf(parsed_statement)

    return cnf

if __name__ == "__main__":
    # Example: (A & B) | (~C & D)
    logic_statement = "(A & B) | (~C & D)"

    # Convert to CNF
    cnf_result = convert_to_cnf(logic_statement)

    print("Original Statement:", logic_statement)
    print("CNF Form:", cnf_result)
```

Output:

```
39 print(fol_to_cnf("bird(x)=>~fly(x)"))
40 print(fol_to_cnf("∃x[bird(x)=>~fly(x)]"))
```

```
~bird(x)|~fly(x)
[~bird(A)|~fly(A)]
```

10. Forward reasoning

Code:

```
from sympy import symbols, Eq, And, Or, Implies, ask, satisfiable

# Define individuals (family members)
John, Mary, Alice, Bob = symbols('John Mary Alice Bob')

# Define predicates
Parent = symbols('Parent')
Grandparent = symbols('Grandparent')

# Define knowledge base
knowledge_base = [
    Eq(Parent(John, Alice), True),
    Eq(Parent(Mary, Alice), True),
    Eq(Parent(Alice, Bob), True),
    Implies(Parent(x, y), Grandparent(x, y)),
]

# Define query
query = Grandparent(John, Bob)

# Perform forward reasoning
def forward_reasoning(knowledge_base, query):
    new_facts = set()

    while True:
        for fact in knowledge_base:
            if ask(fact):
                continue

            if satisfiable(fact):
                new_facts.add(fact)
```

```
    if not new_facts:
        break

    knowledge_base.extend(new_facts)

return ask(query)

# Check if the query is true based on the knowledge base
result = forward_reasoning(knowledge_base, query)

# Print the result
print("Query:", query)
print("Result:", result)
```

Output:

```
95 kb = KB()
96 kb.tell('missile(x)=>weapon(x)')
97 kb.tell('missile(M1)')
98 kb.tell('enemy(x,America)=>hostile(x)')
99 kb.tell('american(West)')
100 kb.tell('enemy(Nono,America)')
101 kb.tell('owns(Nono,M1)')
102 kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
103 kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
104 kb.query('criminal(x)')
105 kb.display()
```

Querying criminal(x):

1. criminal(West)

All facts:

1. missile(M1)
2. weapon(M1)
3. enemy(Nono,America)
4. owns(Nono,M1)
5. hostile(Nono)
6. criminal(West)
7. american(West)
8. sells(West,M1,Nono)