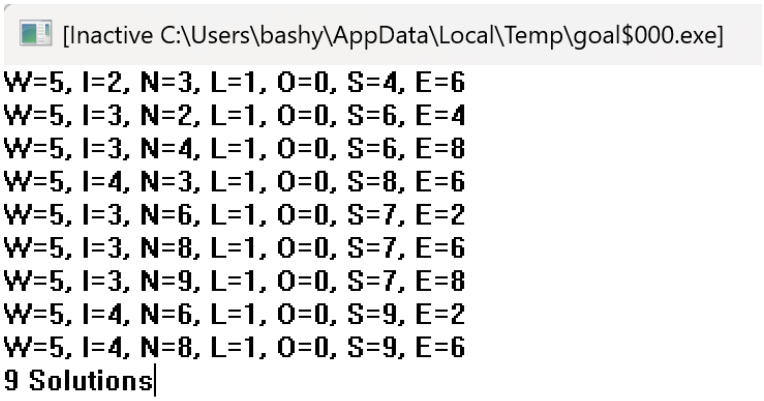
Assignments:

1. **Crypto-Arithmetic Problems:**
   a. **WIN + WIN = LOSE**

```
DOMAINS
        int_list = integer*
PREDICATES
        solution(int_list)
        member(integer, int_list)
CLAUSES
        solution([]).
        solution([W, I, N, L, O, S, E]) :-
                C4 = 1,
                member(C1, [0, 1]),
                member(C2, [0, 1]),
                member(C3, [0, 1]),
                member(W, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(I, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(N, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(L, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(O, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(S, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                member(E, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]),
                W <> I, W <> N, W <> L, W <> O, W <> S, W <> E,
                I <> N, I <> L, I <> O, I <> S, I <> E,
                N <> L, N <> O, N <> S, N <> E,
                L <> O, L <> S, L <> E,
                O <> S, O <> E,
                S <> E,
                N + N = E + 10 * C1,
                I + I + C1 = S + 10 * C2,
                W + W + C2 = O + 10 * C3,
                W + W + C3 = L + 10 * C4,
                L = C4.
        member(X, [X | _]).
        member(X, [_ | Z]) :-
                member(X, Z).
GOAL
    solution([W, I, N, L, O, S, E]).
```

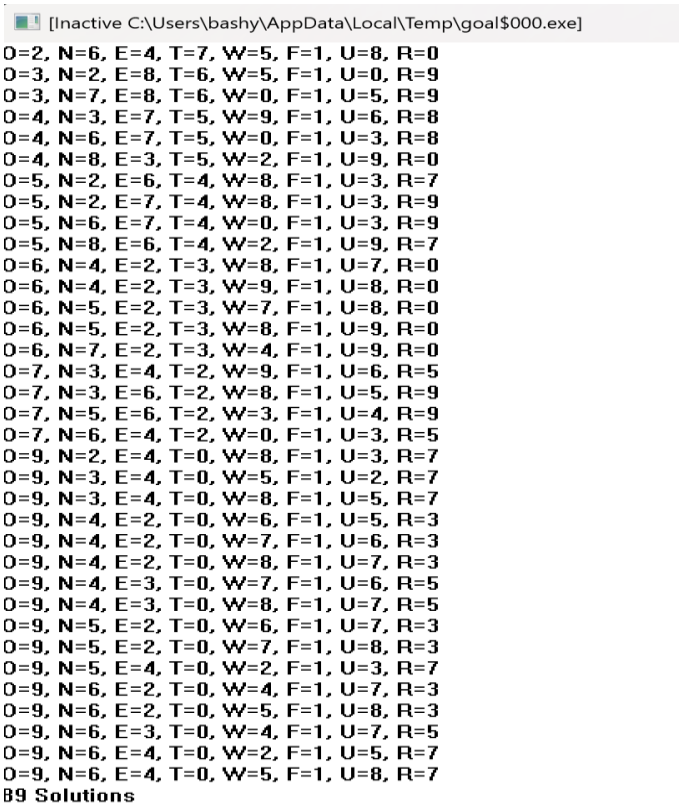
Output:



b. TWO + TWO = FOUR

```
DOMAINS
        int_list = integer*
PREDICATES
        solution(int_list)
        member(integer, int_list)
CLAUSES
        solution([]).
        solution([O, N, E, T, W, F, U, R]) :-
                C3 = 1, member(C1, [0, 1]), member(C2, [0, 1]),
                Digits = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
                member(O, Digits), member(N, Digits), member(E, Digits),
                member(T, Digits), member(W, Digits), member(F, Digits),
                member(U, Digits), member(R, Digits),
                O <> N, O <> E, O <> T, O <> W, O <> F, O <> U, O <> R,
                N <> E, N <> T, N <> W, N <> F, N <> U, N <> R,
                E <> T, E <> W, E <> F, E <> U, E <> R,
                T <> W, T <> F, T <> U, T <> R,
                W <> F, W <> U, W <> R,
                F <> U, F <> R,
                R <> U,
                E + E + O= R + 10*C1,
                N + N + W + C1 = U + 10*C2,
                O + O + T + C2 = O + 10*C3,
                F = C3.
        member(X, [X|T]).
        member(X, [H|T]) :- member(X, T).
GOAL
        solution([O, N, E, T, W, F, U, R]).
```

Output:

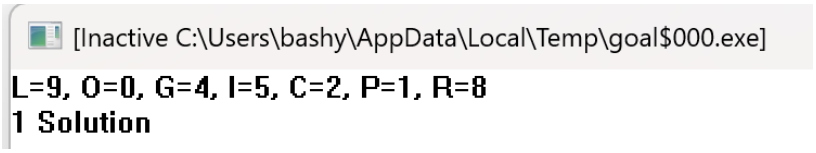


c. LOGIC + LOGIC = PROLOG

```
DOMAINS
        int_list = integer*
PREDICATES
        solution(int_list)
        member(integer, int_list)
CLAUSES
        solution([]).
        solution([L, O, G, I, C, P, R]) :-
                C5 = 1, member(C1, [0, 1]), member(C2, [0, 1]),
                member(C3, [0, 1]), member(C4, [0, 1]),
                Digits = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
                member(L, Digits), member(O, Digits), member(G, Digits),
                member(I, Digits), member(C, Digits), member(P, Digits),
                member(R, Digits),
                L <> O, L <> G, L <> I, L <> C, L <> P, L <> R,
                O <> G, O <> I, O <> C, O <> P, O <> R,
                G <> I, G <> C, G <> P, G <> R,
                I <> C, I <> P, I <> R,
                C <> P, C <> R,
                P <> R,
                C + C = G + 10*C1,
```

```
                I + I + C1 = O + 10*C2,
                G + G + C2 = L + 10*C3,
                O + O + C3 = O + 10*C4,
                L + L + C4 = R + 10*C5,
                P = C5.
        member(X, [X|T]).
        member(X, [H|T]) :- member(X, T).
GOAL
        solution([L, O, G, I, C, P, R]).
```

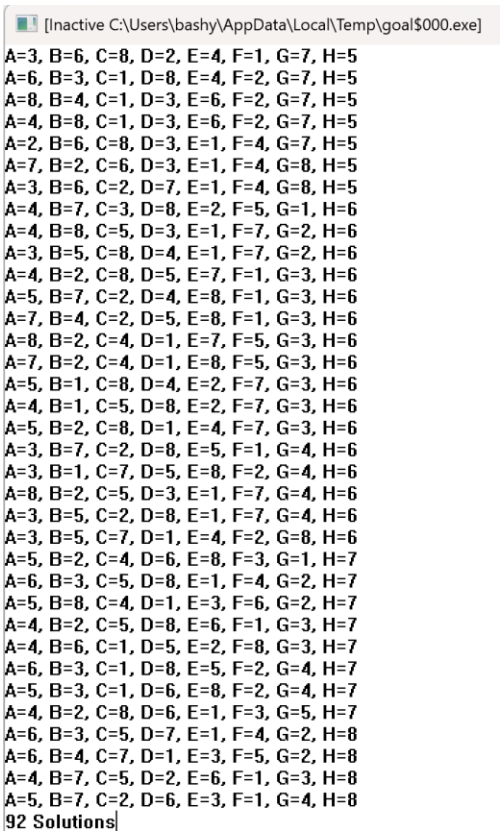
Output:



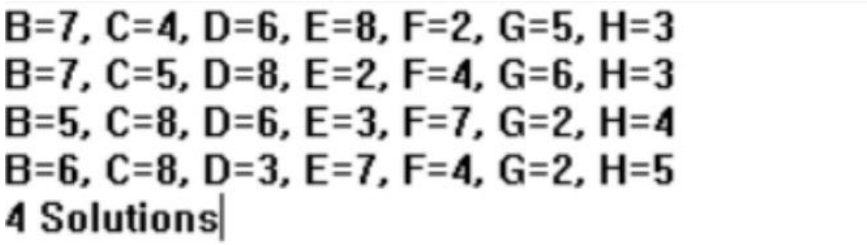
2. **N-Queens Problems:**

```
DOMAINS
        cell = c(integer, integer)
        list = cell*
        int_list = integer*
PREDICATES
        solution(list)
        member(integer, int_list)
        noattack(cell, list)
CLAUSES
        solution([]).
        solution([c(X, Y)|Others]) :-
                solution(Others),
                member(Y, [1, 2, 3, 4, 5, 6, 7, 8]),
                noattack(c(X, Y), Others).
                noattack(_, []).
                noattack(c(X, Y), [c(X1, Y1)|Others]) :-
                Y <> Y1, Y1 - Y <> X1 - X, Y1 - Y <> X - X1,
                noattack(c(X, Y), Others).
        member(X, [X|_]).
        member(X, [_|Z]) :- member(X, Z).
GOAL
        solution([c(1, A), c(2, B), c(3, C), c(4, D),c(5, E), c(6, F), c(7, G), c(8, H)]).
```

Output:



Output: for A=1



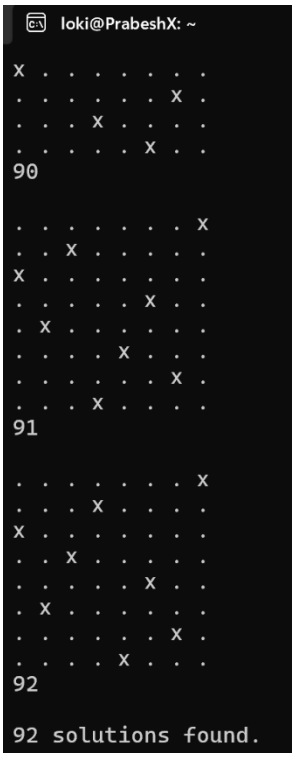
Procedural Implementation:

```
#include <iostream>
#include <vector>
class Queens {
        public:
                int solutionCount, boardSize;
                std::vector<int> cells;

        public:
                Queens(int b) {
                        boardSize = b;
                        solutionCount = 0;
```

```
                cells.resize(boardSize);
                for(int i = 0; i < boardSize; i++) {
                        cells[i] = i;
                }
        }
        void solve(int row = 0) {
                if(row >= boardSize) {
                        printBoard();
                        std::cout << ++solutionCount << "\n\n";
                }
                for(int col = 0; col < boardSize; col++) {
                        if(noAttack(row, col)) {
                                cells[row] = col;
                                solve(row+1);
                        }
                }
        }
        bool noAttack(int row, int col) {
                for(int i = 0; i < row; i++) {
                        if(cells[i] == col or
                        abs(i-row) == abs(cells[i]-col)) return false;
                }
                return true;
        }
        void printBoard() {
                int i = 0;
                for(int x = 0; x < boardSize; x++) {
                        for(int y = 0; y < boardSize; y++) {
                                if(i < boardSize and x == i and y == cells[i]) {
                                        std::cout << "x ";
                                        i++;
                                } else {
                                        std::cout << ". ";
                                }
                        }
                        std::cout << std::endl;
                }
        }
};

int main() {
        int boardSize;
        std::cout << "Enter the board's size: ";
        std::cin >> boardSize;
        Queens solver(boardSize);
        solver.solve();
        std::cout << solver.solutionCount << " solutions found.\n";
```

```
    return 0;
}
```

Output:



3. **Classical-Search Problems:**
    a. **Water-Jug Problem**

```
DOMAINS
        state = c(integer, integer)
        path = state*
        path_list = path*
PREDICATES
        enqueue(path_list, path, path_list)
        member(state, path)
        enqueueFF(path_list, path, path_list, path, path, integer, integer)
        enqueueFS(path_list, path, path_list, path, path, integer, integer)
        enqueueEF(path_list, path, path_list, path, path, integer, integer)
        enqueueES(path_list, path, path_list, path, path, integer, integer)
        enqueueFTS(path_list, path, path_list, path, path, integer, integer)
        enqueueSTF(path_list, path, path_list, path, path, integer, integer)
        fullFirst(state, state, integer, integer)
        fullSecond(state, state, integer, integer)
        emptyFirst(state, state, integer, integer)
        emptySecond(state, state, integer, integer)
        firstToSecond(state, state, integer, integer)
```

```
        secondToFirst(state, state, integer, integer)
        bfs(path_list, integer, path, path, integer, integer)
        start(integer, integer, integer)
CLAUSES
        start(Cx, Cy, G) :- bfs([[c(0, 0)]], G, [c(0, 0)], V, Cx, Cy), !.
        bfs([], _, _, _, _, _) :- write("Search Exhausted"), nl, !.
        bfs([[c(X, Y)|R1]|R2], G, V, V, _, _) :- G = X + Y, write("Found: "),
        P = [c(X, Y)|R1], reverse(P, [], P1), write(P1), nl, !.
        bfs([P|R], G, V, W, Cx, Cy) :- enqueueFF(R, P, Q1, V, V1, Cx, Cy),
        enqueueFS(Q1, P, Q2, V1, V2, Cx, Cy),
        enqueueEF(Q2, P, Q3, V2, V3, Cx, Cy),
        enqueueES(Q3, P, Q4, V3, V4, Cx, Cy),
        enqueueFTS(Q4, P, Q5, V4, V5, Cx, Cy),
        enqueueSTF(Q5, P, Q, V5, W, Cx, Cy),
        bfs(Q, G, W, X, Cx, Cy), !.
        enqueueFF(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- fullFirst(N, S, Cx, Cy),
        not(member(S, V1)),
        enqueue(Q1, [S, N|R], Q2),
        V2 = [S|V1], !.
        enqueueFF(Q, _, Q, V, V, _, _).
        fullFirst(c(X, Y), c(Cx, Y), Cx, _).
        enqueueFS(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- fullSecond(N, S, Cx, Cy),
        not(member(S, V1)),
        enqueue(Q1, [S, N|R], Q2),
        V2 = [S|V1], !.
        enqueueFS(Q, _, Q, V, V, _, _).
        fullSecond(c(X, Y), c(X, Cy), _, Cy).
        enqueueEF(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- emptyFirst(N, S, Cx, Cy),
        not(member(S, V1)),
        enqueue(Q1, [S, N|R], Q2),
        V2 = [S|V1], !.
        enqueueEF(Q, _, Q, V, V, _, _).
        emptyFirst(c(X, Y), c(0, Y), _, _).
        enqueueES(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- emptySecond(N, S, Cx,
        Cy),
        not(member(S, V1)),
        enqueue(Q1, [S, N|R], Q2),
        V2 = [S|V1], !.
        enqueueES(Q, _, Q, V, V, _, _).
        emptySecond(c(X, Y), c(X, 0), _, _).
        enqueueFTS(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- firstToSecond(N, S, Cx,
        Cy),
        not(member(S, V1)), enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
        enqueueFTS(Q, _, Q, V, V, _, _).
        firstToSecond(c(X, Y), c(A, B), Cx, Cy) :- Rem = Cy - Y, Rem >= X, A = 0,
        B = Y + X, !.
        firstToSecond(c(X, Y), c(A, B), Cx, Cy) :- Rem = Cy - Y, Rem < X,
```

```
        A = X - Rem, B = Cy, !.
        enqueueSTF(Q1, [N|R], Q2, V1, V2, Cx, Cy) :- secondToFirst(N, S, Cx,
        Cy),
        not(member(S, V1)), enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
        enqueueSTF(Q, _, Q, V, V, _, _).
        secondToFirst(c(X, Y), c(A, B), Cx, Cy) :- Rem = Cx - X, Rem >= Y,
        A = X + Y, B = 0, !.
        secondToFirst(c(X, Y), c(A, B), Cx, Cy) :- Rem = Cx - X, Rem < Y, A = Cx,
        B = Y - Rem, !.
        enqueue([], Element, [Element]).
        enqueue([Head|Tail], Element, [Head|NewTail]) :-
        enqueue(Tail, Element, NewTail).
        member(Node, [Node|Rest]).
        member(Node, [_|Rest]) :- member(Node, Rest).
        reverse([], L, L) :- !.
        reverse([H|T], L, Z) :- reverse(T, [H|L], Z).
GOAL
        start(3, 5, 7).
```

Output: capacity of jars=3 and 5, to be filled with 7.

```
Found: [c(0,0),c(0,5),c(3,2),c(0,2),c(2,0),c(2,5)]
yes
```

b. Eight-Puzzle Problem

```
DOMAINS
        state = integer*
        path = state*
        path_list = path*
PREDICATES
        enqueue(path_list, path, path_list)
        empty(path_list)
        member(state, path)
        findin(integer, state, integer)
        swap_indices(state, integer, integer, state)
        split_at(integer, state, state, state)
        append(state, state, state)
        enqueueUp(path_list, path, path_list, path, path)
        enqueueDown(path_list, path, path_list, path, path)
        enqueueLeft(path_list, path, path_list, path, path)
        enqueueRight(path_list, path, path_list, path, path)
        bfs(path_list, state, path, path)
        up(state, state)
        down(state, state)
```

```
        right(state, state)
        left(state, state)
        start(state)
        reverse(path, path, path)
        print(path)
CLAUSES
        start(S) :- bfs([[S]], [1, 2, 3, 4, 5, 6, 7, 8, 0], [S], V), !.
        bfs([], _, _, _) :- write("Search Exhausted"), nl, !.
        bfs([[G|R1]|R2], G, V, V) :-
        write("Found: "), reverse([G|R1], [], P), nl, print(P), !.
        bfs([P|R], G, V, W) :-
        enqueueUp(R, P, Q1, V, V1),
        enqueueDown(Q1, P, Q2, V1, V2),
        enqueueRight(Q2, P, Q3, V2, V3),
        enqueueLeft(Q3, P, Q, V3, W), bfs(Q, G, W, X).
        enqueueUp(Q1, [N|Rest], Q2, V1, V2) :-
        up(N, S), not(member(S, V1)), enqueue(Q1, [S|[N|Rest]], Q2),
        V2 = [S|V1], !.
        enqueueUp(Q1, _, Q1, V, V).
        up(S, N) :-
        findin(0, S, I), I > 2, J = I - 3, swap_indices(S, J, I, N), !.
        up(S, S).
        enqueueDown(Q1, [N|Rest], Q2, V1, V2) :-
        down(N, S), not(member(S, V1)), enqueue(Q1, [S|[N|Rest]], Q2),
        V2 = [S|V1], !.
        enqueueDown(Q1, _, Q1, V, V).
        down(S, N) :-
        findin(0, S, I), I < 6, J = I + 3, swap_indices(S, I, J, N), !.
        down(S, S).
        enqueueLeft(Q1, [N|Rest], Q2, V1, V2) :-
        left(N, S), not(member(S, V1)), enqueue(Q1, [S|[N|Rest]], Q2),
        V2 = [S|V1], !.
        enqueueLeft(Q1, _, Q1, V, V).
        left(S, N) :-
        findin(0, S, I), R = I mod 3, R > 0,
        J = I - 1, swap_indices(S, J, I, N), !.
        left(S, S).
        enqueueRight(Q1, [N|Rest], Q2, V1, V2) :-
        right(N, S), not(member(S, V1)),
        enqueue(Q1, [S|[N|Rest]], Q2), V2 = [S|V1], !.
        enqueueRight(Q1, _, Q1, V, V).
        right(S, N) :- findin(0, S, I), R = I mod 3, R < 2,
        J = I + 1, swap_indices(S, I, J, N), !.
        right(S, S).
        empty([]).
        enqueue([], Element, [Element]).
        enqueue([Head|Tail], Element, [Head|NewTail]) :-
```

```
enqueue(Tail, Element, NewTail).
member(Node, [Node|Rest]).
member(Node, [_|Rest]) :- member(Node, Rest).
findin(N, [N|_], 0).
findin(N, [_|Rest], Z) :- findin(N, Rest, L), Z = L + 1.
split_at(0, List, [], List).
split_at(N, [H|T], [H|Front], Rest) :-
N > 0,
N1 = N - 1,
split_at(N1, T, Front, Rest).
append([], L, L).
append([H|T], L, [H|Result]) :- append(T, L, Result).
swap_indices(List, I1, I2, Result) :-
I1 < I2,
split_at(I1, List, Before1, [Elem1|Middle1]),
SplitIndex2 = I2 - I1 - 1,
split_at(SplitIndex2, Middle1, Middle, [Elem2|After]),
append(Before1, [Elem2|Middle], TempList),
append(TempList, [Elem1|After], Result).
reverse([], L, L) :- !.
reverse([H|T], L, Z) :- reverse(T, [H|L], Z).
print([]) :- !.
print([[A, B, C, D, E, F, G, H, I]|R]) :-
write(A), write(" "), write(B), write(" "), write(C), nl,
write(D), write(" "), write(E), write(" "), write(F), nl,
write(G), write(" "), write(H), write(" "), write(I), nl,
nl, print(R).
```

GOAL

start([2, 3, 6, 7, 1, 4, 5, 0, 8]).

Input:

2 3 6

7 1 4

5 0 8

Output:

```
Found:
2 3 6
7 1 4
5 0 8

2 3 6
7 1 4
0 5 8

2 3 6
0 1 4
7 5 8

2 3 6
1 0 4
7 5 8

2 3 6
1 4 0
7 5 8

2 3 0
1 4 6
7 5 8

2 0 3
1 4 6
7 5 8

0 2 3
1 4 6
7 5 8

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
```

c. Missionaries and Cannibals

DOMAINS

state = c(integer, integer, integer, integer, integer, integer, integer)

path = state*

path_list = path*

PREDICATES

enqueue(path_list, path, path_list)

member(state, path)

enqueueMB(path_list, path, path_list, path, path)

moveBoat(state, state)

enqueueLB(path_list, path, path_list, path, path, integer, integer)

leftToBoat(state, state, integer, integer)

enqueueRB(path_list, path, path_list, path, path, integer, integer)

```
        rightToBoat(state, state, integer, integer)
        enqueueBL(path_list, path, path_list, path, path, integer, integer)
        boatToLeft(state, state, integer, integer)
        enqueueBR(path_list, path, path_list, path, path, integer, integer)
        boatToRight(state, state, integer, integer)
        bfs(path_list, state, path, path)
        print(path)
        reverse(path, path, path)
        start
CLAUSES
        start :-
        bfs([[c(0, 0, 0, 0, 3, 3, 1)]], c(3, 3, 0, 0, 0, 0, _),
        [c(0, 0, 0, 0, 3, 3, 1)], W), !.
        bfs([], _, _, _) :- write("Search Exhausted"), nl, !.
        bfs([[G|R1]|R2], G, V, V) :-
        write("Found: "), reverse([G|R1], [], P),
        print(P), nl, !.
        bfs([P|R], G, V, W) :-
                enqueueMB(R, P, Q1, V, V1),
                enqueueLB(Q1, P, Q2, V1, V2, 0, 1),
                enqueueLB(Q2, P, Q3, V2, V3, 0, 2),
                enqueueLB(Q3, P, Q4, V3, V4, 1, 1),
                enqueueLB(Q4, P, Q5, V4, V5, 1, 0),
                enqueueLB(Q5, P, Q6, V5, V6, 2, 0),
                enqueueRB(Q6, P, Q7, V6, V7, 0, 1),
                enqueueRB(Q7, P, Q8, V7, V8, 0, 2),
                enqueueRB(Q8, P, Q9, V8, V9, 1, 1),
                enqueueRB(Q9, P, Q10, V9, V10, 1, 0),
                enqueueRB(Q10, P, Q11, V10, V11, 2, 0),
                enqueueBL(Q11, P, Q12, V11, V12, 0, 1),
                enqueueBL(Q12, P, Q13, V12, V13, 0, 2),
                enqueueBL(Q13, P, Q14, V13, V14, 1, 1),
                enqueueBL(Q14, P, Q15, V14, V15, 1, 0),
                enqueueBL(Q15, P, Q16, V15, V16, 2, 0),
                enqueueBR(Q16, P, Q17, V16, V17, 0, 2),
                enqueueBR(Q17, P, Q18, V17, V18, 0, 1),
                enqueueBR(Q18, P, Q19, V18, V19, 1, 1),
                enqueueBR(Q19, P, Q20, V19, V20, 1, 0),
                enqueueBR(Q20, P, Q, V20, W, 2, 0),
                bfs(Q, G, W, X).
        enqueueMB(Q1, [N|R], Q2, V1, V2) :-
        moveBoat(N, S), not(member(S, V1)),
        enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
        enqueueMB(Q, _, Q, V, V).
        moveBoat(c(A, B, 0, 0, E, F, G), c(A, B, 0, 0, E, F, G)) :- !.
        moveBoat(c(Lc, Lm, Bc, Bm, Rc, Rm, 0), X) :-
        Lc <= Lm, Rc + Bc <= Rm + Bm, X = c(Lc, Lm, Bc, Bm, Rc, Rm, 1), !.
```

```
moveBoat(c(Lc, Lm, Bc, 0, Rc, 0, 0), X) :-
Lc <= Lm, X = c(Lc, Lm, Bc, 0, Rc, 0, 1), !.
moveBoat(c(Lc, 0, Bc, Bm, Rc, Rm, 0), X) :-
Rc + Bc <= Rm + Bm, X = c(Lc, 0, Bc, Bm, Rc, Rm, 1), !.
moveBoat(c(Lc, Lm, Bc, Bm, Rc, Rm, 1), X) :-
Rc <= Rm, Lc + Bc <= Lm + Bm, X = c(Lc, Lm, Bc, Bm, Rc, Rm, 0), !.
moveBoat(c(Lc, 0, Bc, 0, Rc, Rm, 1), X) :-
Rc <= Rm, X = c(Lc, 0, Bc, 0, Rc, Rm, 0), !.
moveBoat(c(Lc, Lm, Bc, Bm, Rc, 0, 1), X) :-
Lc + Bc <= Lm + Bm, X = c(Lc, Lm, Bc, Bm, Rc, 0, 0), !.
moveBoat(S, S).
enqueueLB(Q1, [N|R], Q2, V1, V2, C, M) :-
leftToBoat(N, S, C, M), not(member(S, V1)),
enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
enqueueLB(Q, _, Q, V, V, _, _).
leftToBoat(c(Lc, Lm, Bc, Bm, Rc, Rm, 0), X, C, M) :-
C <= Lc, M <= Lm, C + Bc + M + Bm <= 2,
NLc = Lc - C, NLm = Lm - M, NBc = Bc + C, NBm = Bm + M,
X = c(NLc, NLm, NBc, NBm, Rc, Rm, 0), !.
leftToBoat(S, S, _, _).
enqueueRB(Q1, [N|R], Q2, V1, V2, C, M) :-
rightToBoat(N, S, C, M), not(member(S, V1)),
enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
enqueueRB(Q, _, Q, V, V, _, _).
rightToBoat(c(Lc, Lm, Bc, Bm, Rc, Rm, 1), X, C, M) :-
C <= Rc, M <= Rm, C + Bc + M + Bm <= 2,
NRc = Rc - C, NRm = Rm - M, NBc = Bc + C, NBm = Bm + M,
X = c(Lc, Lm, NBc, NBm, NRc, NRm, 1), !.
rightToBoat(S, S, _, _).
enqueueBL(Q1, [N|R], Q2, V1, V2, C, M) :-
boatToLeft(N, S, C, M), not(member(S, V1)),
enqueue(Q1, [S, N|R], Q2), V2 = [S|V1], !.
enqueueBL(Q, _, Q, V, V, _, _).
boatToLeft(c(Lc, Lm, Bc, Bm, Rc, Rm, 0), X, C, M) :- C <= Bc, M <= Bm,
NLc = Lc + C, NLm = Lm + M, NBc = Bc - C, NBm = Bm - M,
X = c(NLc, NLm, NBc, NBm, Rc, Rm, 0), !.
boatToLeft(S, S, _, _).
enqueueBR(Q1, [N|R], Q2, V1, V2, C, M) :- boatToRight(N, S, C, M),
not(member(S,enqueueBR(Q, _, Q, V, V, _, _).
boatToRight(c(Lc, Lm, Bc, Bm, Rc, Rm, 1), X, C, M) :- C <= Bc, M <= Bm,
NRc = Rc + C, NRm = Rm + M, NBc = Bc - C, NBm = Bm - M,
X = c(Lc, Lm, NBc, NBm, NRc, NRm, 1), !.
boatToRight(S, S, _, _).
enqueue([], Element, [Element]).
enqueue([Head|Tail], Element, [Head|NewTail]) :-
enqueue(Tail, Element, NewTail).
member(Node, [Node|Rest]).
```

```
member(Node, [_|Rest]) :- member(Node, Rest).
reverse([], L, L) :- !.
reverse([H|T], L, Z) :- reverse(T, [H|L], Z).
print([]) :- !.
print([c(Lc, Lm, Bc, Bm, Rc, Rm, B)|R]) :-
write("Left: "), write(Lc), write(" "), write(Lm), write(", Boat: "),
write(Bc), write(" "), write(Bm), write(" P: "),
write(B), write(", Right: "), write(Rc), write(" "),
write(Rm), nl, print(R).
GOAL
start.
```

Output:

```
Found: Left: 0 0, Boat: 0 0 P: 1, Right: 3 3
Left: 0 0, Boat: 2 0 P: 1, Right: 1 3
Left: 0 0, Boat: 2 0 P: 0, Right: 1 3
Left: 1 0, Boat: 1 0 P: 0, Right: 1 3
Left: 1 0, Boat: 1 0 P: 1, Right: 1 3
Left: 1 0, Boat: 2 0 P: 1, Right: 0 3
Left: 1 0, Boat: 2 0 P: 0, Right: 0 3
Left: 2 0, Boat: 1 0 P: 0, Right: 0 3
Left: 2 0, Boat: 1 0 P: 1, Right: 0 3
Left: 2 0, Boat: 0 0 P: 1, Right: 1 3
Left: 2 0, Boat: 0 2 P: 1, Right: 1 1
Left: 2 0, Boat: 0 2 P: 0, Right: 1 1
Left: 2 1, Boat: 0 1 P: 0, Right: 1 1
Left: 1 1, Boat: 1 1 P: 0, Right: 1 1
Left: 1 1, Boat: 1 1 P: 1, Right: 1 1
Left: 1 1, Boat: 0 0 P: 1, Right: 2 2
Left: 1 1, Boat: 0 2 P: 1, Right: 2 0
Left: 1 1, Boat: 0 2 P: 0, Right: 2 0
Left: 1 3, Boat: 0 0 P: 0, Right: 2 0
Left: 0 3, Boat: 1 0 P: 0, Right: 2 0
Left: 0 3, Boat: 1 0 P: 1, Right: 2 0
Left: 0 3, Boat: 2 0 P: 1, Right: 1 0
Left: 0 3, Boat: 2 0 P: 0, Right: 1 0
Left: 1 3, Boat: 1 0 P: 0, Right: 1 0
Left: 1 3, Boat: 1 0 P: 1, Right: 1 0
Left: 1 3, Boat: 2 0 P: 1, Right: 0 0
Left: 1 3, Boat: 2 0 P: 0, Right: 0 0
Left: 3 3, Boat: 0 0 P: 0, Right: 0 0

yes
```

Discussion

In constraint programming, constraints are used to model problems like crypto-arithmetic, where letters are mapped to digits to satisfy a sum constraint, and the N-queens problem, where queens are placed in positions that avoid attacks. However, when the number of unique letters increases, as in crypto-arithmetic, the constraints become more complex and computationally demanding. In classical-search problems, the breadth-first search (BFS) algorithm is applied to find the shortest path in problems with smaller state spaces, such as Missionaries and Cannibals and Water Jugs. While BFS works well for these, its exponential time and space complexity cause issues in larger state spaces, as seen in the Eight Puzzle problem, where the limited resources of Visual Prolog v5.1 exacerbate these challenges.

Conclusion

This lab, we demonstrated the strengths and limitations of constraint programming and breadth-first search (BFS). Constraint programming efficiently modeled problems like crypto-arithmetic and N-queens, while BFS worked well for smaller state spaces, such as the Missionaries and Cannibals problem. However, both approaches faced challenges with scalability in larger or more complex problems like the Eight Puzzle.