Grad AI. 15-780 Fall, 2006

Homework 1 Solution

1. **Search(40 pts)**.

   (a) Expansion order for:

   - DFS (**2 pts**): $a \to e \to i \to m \to q \to u \to v \to w \to x$
   - BFS (**2 pts**) : $a \to e \to b \to i \to c \to m \to j \to g \to d \to q \to n \to k \to h \to u \to r \to o \to l \to v \to s \to p \to w \to t \to x$
   - Heuristic search (2pts): $a \to e \to i \to m \to q \to u \to v \to w \to x$
   - A* (**2 pts**): Assume we break ties between states according to their coordinates: top to bottom, then left to right within a row.
     $a \to e \to i \to m \to q \to u \to b \to j \to n \to r \to v \to c \to g \to k \to o \to s \to w \to d \to h \to l \to p \to t \to x$
   - (**2 pts**) h is admissible. A better heuristic h' could be Manhattan distance or Euclidean distance.

   (b) coding and report. (**30 pts**) Sample code credit: *Geoff Hollinger*.

2. **Constraint Satisfaction Search (30 pts)**.

   (a) Problem formulation (**10 pts**).

   - State: consist of nine Boolean variables representing each person of the group and raft on the bank of river from which they started. Write as

     $$(Man, Woman, Boy1, Boy2, Girl1, Girl2, Police, Thief, Raft).$$

     Note states consists seven variables if we does not distinguish between individual boys and girls

     $$(Man, Woman, Boy, Girl, Police, Thief, Raft),$$

     where $Boy \in \{0, 1, 2\}$ and $Girl \in \{0, 1, 2\}$, and other variables are Boolean.
   - Start state: (1, 1, 1, 1, 1, 1, 1, 1, 1) or (1, 1, 2, 2, 1, 1, 1) .
   - Goal state: (0, 0, 0, 0, 0, 0, 0, 0, 0) or (0, 0, 0, 0, 0, 0, 0).
   - Operators: take one or two people onto the raft and across the river. There are at most 15 (11) operators (listed in the first column of the tables below). Most states have much fewer because of the rule constraints (e.g. the thief must be with the policeman or be alone). Therefor the operators are valid only if their corresponding precondition evaluates to true. Those preconditions are listed in the second column of the tables below.
   - Preconditions:
     i. People in the operator should be at the same bank as the raft.
     (e.g Man = Raft for the first operator)

ii. It's only OK to move the Man if either both Girls are not on the destination side, or the Woman is on the destination side.

$(\neg Man \wedge ((\neg Girl1 \wedge \neg Girl2) \vee Woman)) \vee (Man \wedge ((Girl1 \wedge Girl2) \vee \neg Woman))$

iii. It's only OK to move the Woman if either both Boys are not on the destination side, or the Man is on the destination side.

$(\neg Woman \wedge ((\neg Boy1 \wedge \neg Boy2) \vee Man)) \vee (Woman \wedge ((Boy1 \wedge Boy2) \vee \neg Man))$

iv. It's only OK to move the police without thief on raft if the thief is alone on the start side.
$(\neg Police \wedge \neg Theif \wedge Man \wedge Woman \wedge Boy1 \wedge Boy2 \wedge Girl1 \wedge Girl2) \vee$
$(Police \wedge Theif \wedge \neg Man \wedge \neg Woman \wedge \neg Boy1 \wedge \neg Boy2 \wedge \neg Girl1 \wedge \neg Girl2)$

- To get preconditions if you do not distinguish boys and girls, replace
  - $Boy1 \wedge Boy2$ with $Boy = 2$,
  - $\neg Boy1 \wedge \neg Boy2$ with $Boy = 0$,
  - $Girl1 \wedge Girl2$ with $Girl = 2$,
  - $\neg Girl1 \wedge \neg Girl2$ with $Girl = 0$

Operators (15)	Preconditions
Man + Raft	i ∧ ii
Man + Boy1 + Raft	i ∧ ii
Man + Boy2 + Raft	i ∧ ii
Woman + Raft	i ∧ iii
Woman + Girl1 + Raft	i ∧ iii
Woman + Girl2 + Raft	i ∧ iii
Man + Woman + Raft	i ∧ ii ∧ iii
Police + Raft	i ∧ iv
Police + Thief + Raft	i
Police + Boy1 + Raft	i ∧ iv
Police + Boy2 + Raft	i ∧ iv
Police + Girl1 + Raft	i ∧ iv
Police + Girl2 + Raft	i ∧ iv
Police + Man + Raft	i ∧ ii ∧ iv
Police + Woman + Raft	i ∧ iii ∧ iv

Operators (11)	Preconditions
Man + Raft	i $\wedge$ ii
Man + Boy + Raft	i $\wedge$ ii
Woman + Raft	i $\wedge$ iii
Woman + Girl + Raft	i $\wedge$ iii
Man + Woman + Raft	i $\wedge$ ii $\wedge$ iii
Police + Raft	i $\wedge$ iv
Police + Thief + Raft	i
Police + Boy + Raft	i $\wedge$ iv
Police + Girl + Raft	i $\wedge$ iv
Police + Man + Raft	i $\wedge$ ii $\wedge$ iv
Police + Woman + Raft	i $\wedge$ iii $\wedge$ iv

(b) coding and report (**20 pts**). Sample code credit: *Rosen Diankov*.

3. **Spatial Planning (30 pts)**.

(a) C-space plot (**12 pts**): shown in Figure 1. The closed region in each graph marked with "c-space" is the interior of c-space. The blue squares are just inside the c-space. Sample code credit: *Juan Fasola*.

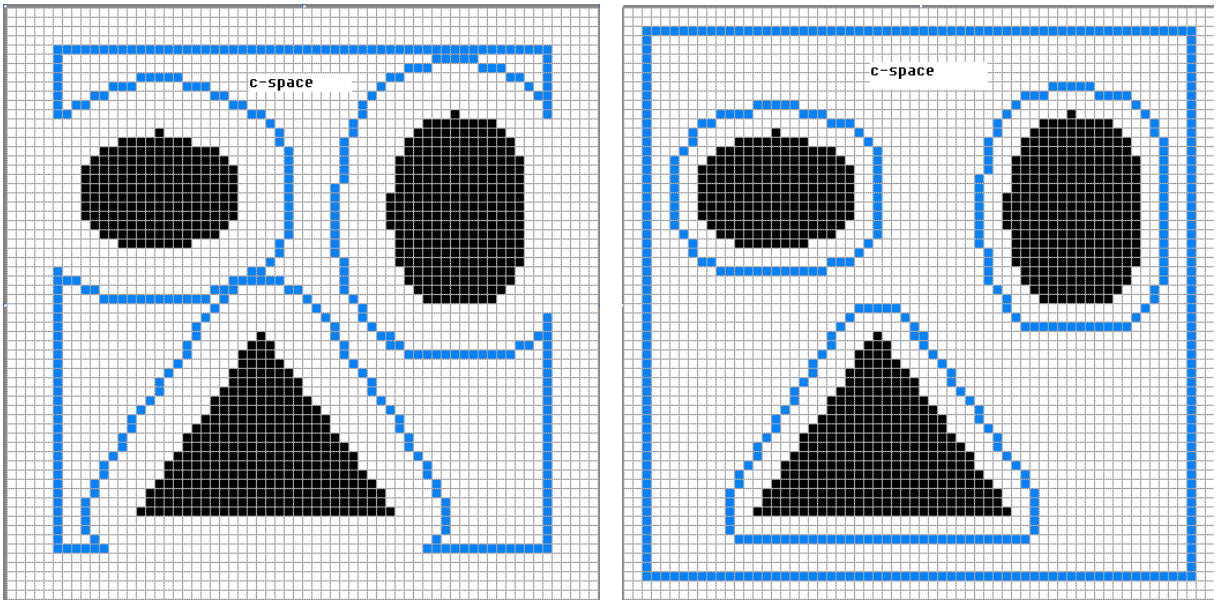

Figure 1: C-space. Left: a circle with radius 5; right: a 5×5 square.

(b) $q_1 - q_2$ plot (**18 pts**): shown in Figure 2. Sample code credit: *Myung Hwangbo*.

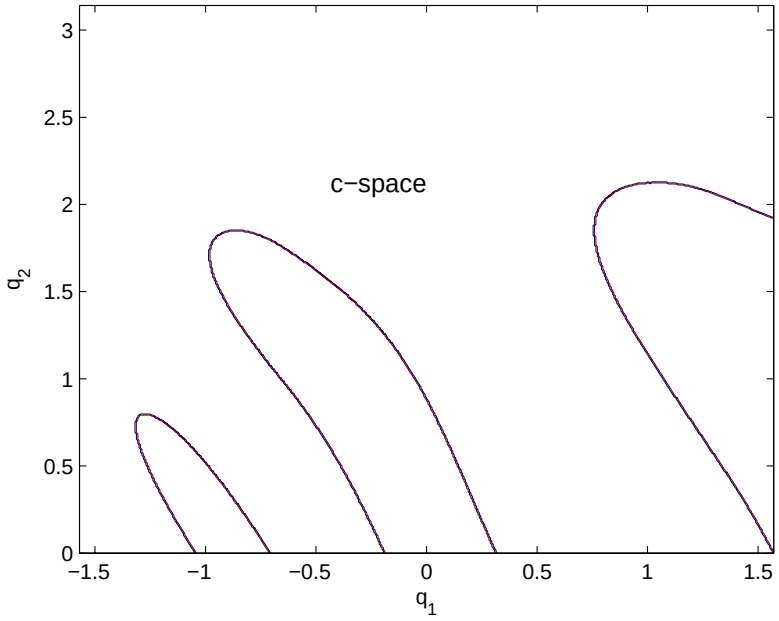

Figure 2: Contour of $q_1 - q_2$ plot.