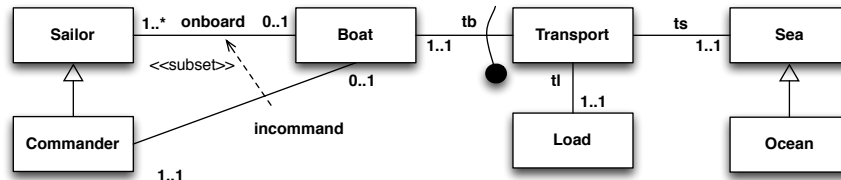
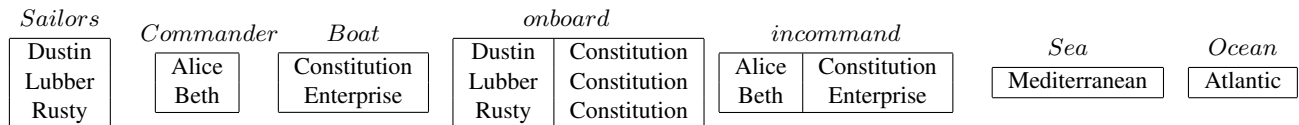


**Exercise 1.** Express the following UML class diagram in *FOL*.

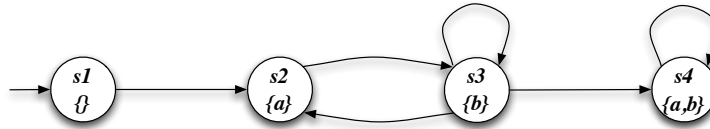


**Exercise 2.** Consider the above UML class diagram and the following (partial) instantiation.



1. Check whether the above instantiation, once completed, is correct, and explain why it is or it is not.
2. Express in FOL the following queries and evaluate them over the completed instantiation:
  - (a) Return the commanders that command a boat with at least a sailor who is not a commander.
  - (b) Return the boats that have on board only commanders
  - (c) Return the boats that have on board all the sailors who are not commanders.

**Exercise 3.** Model check the Mu-Calculus formula  $\nu X. \mu Y. ((a \wedge \langle next \rangle X) \vee (\neg b \wedge \langle next \rangle Y))$  and the CTL formula  $EF(a \wedge EX(AGb))$  (showing its translation in Mu-Calculus) against the following transition system:



**Exercise 4.** Check whether the following Hoare triple is correct, using as invariant  $i + j \leq 10$ .

$\{i=0 \text{ AND } j=10\} \quad \text{while}(i<10) \text{ do } \{j=j-1; i:= i+1\} \quad \{j=0\}$

**Exercise 5.** Given the following boolean conjunctive queries:

$q1() :- \text{edge}(r,b), \text{edge}(b,g), \text{edge}(g,r).$

$q2() :- \text{edge}(i,f), \text{edge}(f,v), \text{edge}(v,i), \text{edge}(i,a), \text{edge}(a,v), \text{edge}(a,s), \text{edge}(s,i).$

check whether  $q1$  is contained into  $q2$ , explaining the technique used and, in case of containment, showing the homomorphism between the canonical databases.