Titolo esplicativo

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1 List of predicates

2 Specification of the system

2.1 Specification of the working cell

1. The pallet has to be somewhere (a specific cell).

2.2 Specification of the robot

1. It is impossible that the local bin is empty and full at the same time.

$$\neg(\mathsf{isLocalBinEmpty} \wedge \mathsf{isLocalBinFull})$$

2.2.1 Specification of the arm

1. The joint has to be close to the cart.

   $\mathsf{isCartAt}(x, y) \rightarrow \mathsf{isJointAt}(x, y) \vee \mathsf{isJointAt}(x+1, y) \vee \mathsf{isJointAt}(x, y+1) \vee \mathsf{isJointAt}(x+1, y+1) \vee \mathsf{isJointAt}$

2. The end effector has to be close to the joint.

   $\mathsf{isJointAt}(x, y) \rightarrow \mathsf{isEndEffectorAt}(x, y) \vee \mathsf{isEndEffectorAt}(x+1, y) \vee \mathsf{isEndEffectorAt}(x, y+1) \vee \mathsf{isEndEffecto}$

3. The joint can move close to its position.

   $\mathsf{isJointMoving} \wedge \mathsf{isJointAt}(x, y) \rightarrow Dist(\mathsf{isJointAt}(x+1, y) \vee \mathsf{isJointAt}(x, y+1) \vee \mathsf{isJointAt}(x+1, y+1) \vee \mathsf{isJ}$

4. The end effector can move close to its position.

   $\mathsf{isEndEffectorMoving} \wedge \mathsf{isEndEffectorAt}(x, y) \rightarrow Dist(\mathsf{isEndEffectorAt}(x+1, y) \vee \mathsf{isEndEffectorAt}(x, y+1) \vee$

5. The operator is on the left of the cart if its in the adjecent cell to the left.

   $$\mathsf{isOpOnTheLeft} \longleftrightarrow \mathsf{isCartAt}(x, y) \wedge \mathsf{isOperatorAt}(x-2, y)$$

6. The operator is on the right of the cart if its in the adjecent cell to the right.

   $$\mathsf{isOpOnTheRight} \longleftrightarrow \mathsf{isCartAt}(x, y) \wedge \mathsf{isOperatorAt}(x+1, y)$$

2.2.2 Specification of the cart

1. It is impossible that the cart is moving and is still at the same time.

$$\neg(\mathsf{isCartMoving} \wedge \mathsf{isCartStill})$$

2. The cart is moving or is still.

$$\mathsf{isCartMoving} \vee \mathsf{isCartStill}$$

3. The cart is moving if and only if it is moving at some speed.

$$\mathsf{isCartMoving} \leftrightarrow (\mathsf{isCartMovingFast} \vee \mathsf{isCartMovingMedium} \vee \mathsf{isCartMovingSlow})$$

4. It is impossible that the cart is moving at different speeds at the same time.

$$\mathsf{isCartMovingFast} \rightarrow (\neg\mathsf{isCartMovingMedium} \wedge \neg\mathsf{isCartMovingSlow})$$

$$\mathsf{isCartMovingMedium} \rightarrow (\neg\mathsf{isCartMovingFast} \wedge \neg\mathsf{isCartMovingSlow})$$

$$\mathsf{isCartMovingSlow} \rightarrow (\neg\mathsf{isCartMovingMedium} \wedge \neg\mathsf{isCartMovingFast})$$

5. The cart is moving if and only if is moving to the bin or to the pallet.

$$\mathsf{isCartMoving} \leftrightarrow (\mathsf{isCartMovingToBin} \vee \mathsf{isCartMovingToPallet})$$

6. It is impossible that the cart is moving to the bin and to the pallet at the same time.

$$\neg(\mathsf{isCartMovingToBin} \wedge \mathsf{isCartMovingToPallet})$$

7. The cart has to be in a cell.

8. The cart can't be in more than one cell.

9. Slow speed is one cell per time step. $2 \leq x \leq 13, 1 \leq y \leq 3$

$$\begin{aligned}\mathsf{isCartMovingSlow} \wedge \mathsf{isCartAt(x, y)} \rightarrow & Dist(\mathsf{isCartAt(x + 1, y)} \vee \mathsf{isCartAt(x, y + 1)} \\ & \vee \mathsf{isCartAt(x - 1, y)} \vee \mathsf{isCartAt(x, y - 1)}, 1)\end{aligned}$$

10. Fast speed is two cells per time step.

$$\mathsf{isCartMovingFast} \wedge \mathsf{isCartAt}(\mathsf{x},\mathsf{y}) \rightarrow Dist(\mathsf{isCartAt}(\mathsf{x}+2,\mathsf{y}) \vee \mathsf{isCartAt}(\mathsf{x},\mathsf{y}+1) \vee \mathsf{isCartAt}(\mathsf{x}-2,\mathsf{y}) \vee \mathsf{isCart}$$

11. When the cart is moving, the robot has to be still

$$\mathsf{isCartMoving} \rightarrow \mathsf{isRobotResting}resting1$$

12. The robot is resting when both the joint and the end effector are in the same cell of the cart.

$$\mathsf{isRobotRestingisCartAt}(\mathsf{x},\mathsf{y}) \rightarrow \mathsf{isEndEffectorAt}(\mathsf{x},\mathsf{y}) \wedge \mathsf{isJointAt}(\mathsf{x},\mathsf{y}))$$

13. The cart has to move to the bin when the local bin is empty.

$$\mathsf{isLocalBinEmpty} \wedge \neg\mathsf{isOpOnTheLeft} \wedge \mathsf{isRobotResting}24 \rightarrow \mathsf{isCartMovingeLeft}$$

14. The cart is moving left if is moving on the adjecent left cell at distance one or two.

$$\mathsf{isCartMovingeLeft} \longleftrightarrow (\mathsf{isCartAt}(\mathsf{x},\mathsf{y}) \rightarrow Dist(\mathsf{isCartAt}(\mathsf{x}-1,\mathsf{y}),1)) \vee (\mathsf{isCartAt}(\mathsf{x},\mathsf{y}) \rightarrow Dist(\mathsf{isCartAt}(\mathsf{x}$$

15. The cart has to move to the pallet when the local bin is full.

$$\mathsf{isLocalBinFull} \wedge \neg\mathsf{isOpOnTheRight} \wedge \mathsf{isRobotResting}134 \rightarrow \mathsf{isCartMovingRight}$$

16. The cart is moving right if is moving on the adjecent right cell at distance one or two.

$$\mathsf{isCartMovingRight} \longleftrightarrow (\mathsf{isCartAt}(\mathsf{x},\mathsf{y}) \rightarrow Dist(\mathsf{isCartAt}(\mathsf{x}+1,\mathsf{y}),1)) \vee (\mathsf{isCartAt}(\mathsf{x},\mathsf{y}) \rightarrow Dist(\mathsf{isCartAt}(\mathsf{x}$$

2.3 Specification of the operator

1. The operator is trapped only if it is close to the robot.

$$\mathsf{isOperatorTrapped} \rightarrow \mathsf{isOperatorClose}$$

2. The operator is close to the robot or away.

$$\mathsf{isOperatorClose} \vee \mathsf{isOperatorAway}$$

3. The operator can't be close to the robot and away at the same time.

$$\neg(\mathsf{isOperatorClose} \wedge \mathsf{isOperatorAway})$$

4. The body of the operator has to be somewhere.
5. Arms of the operator have to be close to the body.

$$\mathsf{isBodyAt}(x, y) \rightarrow \mathsf{isRightArmAt}(x, y) \vee \mathsf{isRightArmAt}(x+1, y) \vee \mathsf{isRightArmAt}(x, y+1) \vee \mathsf{isRightArmAt}(x+$$

$$\mathsf{isBodyAt}(x, y) \rightarrow \mathsf{isLeftArmAt}(x, y) \vee \mathsf{isLeftArmAt}(x+1, y) \vee \mathsf{isLeftArmAt}(x, y+1) \vee \mathsf{isLeftArmAt}(x+1, y-$$

3 Specification of the safety properties

- The cart and the operator cannot be in the same cell of the pallet.