Course

Intelligent Agents

Part 2: Knowledge-based Robots

– Interaction levels –

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Interaction Ability

The slides report on the classification of interaction abilities as presented in the European document "Robotics 2020 Multi-Annual Roadmap."

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The notion is presented as follows

The ability of a system to interact physically, cognitively and socially either with users, operators or other systems around it, including other robots.
The ability to interact may be as simple as the use of a communication protocol, or as advanced as holding an interactive conversation in a social context.

Physical Interaction

The ability to physically interact covers four specific areas of interaction:

- Human-robot interaction
- Human-robot interaction feedback
- Robot-robot Interaction
- Interaction safety

Human-Robot Interaction Levels (I)

- Level 0 - No interaction
  It is possible that some robots will effectively have no operational interaction with a user.
- Level 1 - Direct control
  The user provides control of the robot moment to moment. The system can translate, alter, or block these controls within parameters set by the user or system.
- Level 2 - Direct physical interaction
  The user controls the robot by physically interacting with it. The robot reacts to the user interaction by feeding back physical information to the user via the contact point.

Human-Robot Interaction Levels (II)

- Level 3 - Position selection
  The system is able to execute pre-defined actions autonomously. The user selects the subsequent action at the completion of each action.
- Level 4 - Traded autonomy
  The system is able to operate autonomously during some parts of a task or in some tasks. Once this task or sub-task is complete the user will either select the subsequent task or intervene to control the system by direct interaction to carry out a task. This results in alternating sequences of autonomous and direct control of the system by the user.
- Level 5 - Task sequence control
  The system is able to execute sub-tasks autonomously, these sub-tasks will involve a higher level of decisional autonomy than the pre-defined tasks in Level 3. On completion of the sub-task user interaction is required to select the next sub-task.

Human-Robot Interaction Levels (III)

- Level 6 - Supervised autonomy
  The robot system is able to execute a task autonomously in most operating conditions. The system is able to recognise when it is unable to proceed or when it requires user input to select alternative strategies or courses of action.
- Level 7 - Task selection
  The system is able to autonomously execute tasks but requires the user to select between strategic task alternatives in order to execute a mission.
- Level 8 - Mission Goal setting
  The system is able to execute tasks to achieve a mission. The user is able to interact with the system to direct the overall objectives of the mission.

Human-Robot Interaction Feedback Levels

The ability to command a robot depends on the users perception of the state of the robot. This set of levels defines how this state information can be fed back to a user who is operating the robot.

Human-Robot Interaction Feedback Levels (I)

- Level 0   No feedback
  The robot system does not provide any feedback to the user
- Level 1   Visual feedback
  The user is able to assess the state of the robot by direct observation. The robot system does not provide any means of feeding back information to the user.
- Level 2   Vision data feedback
  The system feedbacks visual information about the state of the operating environment around the robot based on data captured locally at the robot. The user must interpret this visual imagery to assess the state of the robot or its environment.

Human-Robot Interaction Feedback Levels (II)

- Level 3 Simple haptic feedback
  The robot system is able to feedback a physical force that represents the forces at the end effector of the robot. The force feedback is delivered to the user via a single point of contact, for example a joystick.
- Level 4 - Augmented haptic feedback
  The system is able to feedback to the operator signals and forces that augment the force information from the end effector such that the augmentation enhances the interaction between the user and the robot.
- Level 5 Multiple point feedback
  The robot system is able to feedback to the operator signals and physical forces that represent multiple forces at the end effector of the robot. The force feedback is delivered to the user via multiple points of contact, for example to each finger of the operators hand.

Human-Robot Interaction Feedback Levels (III)

- Level 6 Augmented multiple point feedback
  The robot system is able to augment with additional information the feedback of a set of physical forces that represent the forces at the end effector of the robot. The force feedback is delivered to the user via a multiple point of contact, for example to each finger of the operators hand.
- Level 7 Tele-presence
  The system is able to provide multi-modal feedback to the operator such that they experience tele-presence. Typically this requires close synchronisation between different feedback channels.
- Level 8 Augmented tele-presence
  The system is able to augment the experience of tele-presence with additional information that enhances the interaction between the user and the robot.

Human-Robot Interaction Safety Levels

It is assumed that all robots meet safety criteria appropriate to their operating environment with respect to electrical and battery safety requirements, typically specified by European CE marking criteria.

It is also expected that appropriate safety criteria have been applied with respect to consumables used by the robot. For example heated liquids, liquids under pressure, or chemical agents.

Human-Robot Interaction Safety Levels (I)

- Level 0 - Intrinsic safety
  The mechanism of the robot is safe because by design it cannot exert a force that is damaging to a person at any time during its operating cycle. The maintenance of this level of safety does not depend on software.
- Level 1 - Basic safety
  The robot operates with a basic level of safety appropriate to the task. Maintaining safe operation may depend on the operator being able to stop operation or continuously enable the operating cycle. The maintenance of this level of safety does not depend on software.
- Level 2 - Basic operator safety
  The robot is made safe for the operator by physically bounding the operating space of the robot. Access gates trigger stop commands to the robot. The robot will not operate unless the bounding space is closed.

Human-Robot Interaction Safety Levels (II)

- Level 3 - User detection
  The robot is informed when a user enters the work zone.
  The robot operates in an safe way while the user is
  present in the operating zone.
- Level 4 - Work space detection
  The robot operates within a well defined space where a
  zone of safe operation is identified to the operator and
  programmed into the robot. While the robot is occupying
  the safe zone it will control its motion such that it is safe.
  The system may also use sensing to detect that the user
  does not enter the unsafe zone.
- Level 5 - Dynamic User detection
  The robot or its support systems detect users within its
  operating zone and dynamically defines a safe zone that
  envelopes the user where the robot controls its motion to
  be safe.

Human-Robot Interaction Safety Levels (III)

- Level 6 - Reactive safety
  The robot is designed to be safe under all reasonable circumstances such that if it impacts a person the impact forces are minimised below the level that may cause injury during the impact.
- Level 7 - Dynamic safety
  The robot is able to exert strong forces as a part of an interaction task with a user, but recognises when the use of these forces may endanger the user. In this case the robot alters its motion to ensure safe operation.
- Level 8 - Context dependent safety
  The robot is able to recognise circumstances where it needs to behave in a safe way because it is uncertain about the nature of the environment.