Criteria for selection of robotic manipulators for trainable robots guided by Skilligent

Technical guidelines

Revision 4

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1 Introduction

This document outlines guidelines for the selection/design of a robotic arm suitable for use on trainable robots guided by Skilligent Robot Learning and Behavior Control System.

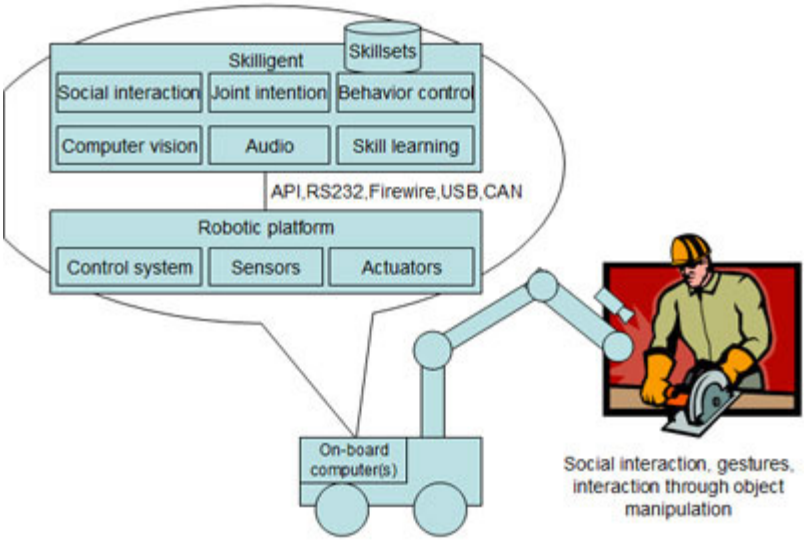

Figure 1 A logical view of Skilligent software architecture

The fact that the robot is trained through interaction with humans, applies specific requirements to the design especially in the areas of *safety* and *sensing*.

Skilligent is a robotic behavior control system with robot learning and social interaction capabilities. The software allows robots to learn directly from demonstrations made by their users. Such robots can be trained by non-professionals rather than programmed by robotics engineers. This greatly increases flexibility and usefulness of robots and reduces the cost of ownership.

The software is based on several robot learning technologies including *robot learning from demonstration*, natural robot-to-human interaction, learning of action-to-concept relations, *hierarchical behavior control*, computer vision and a few others.

2 Checklist table

ID	Feature/Requirement		Comments
	Touch sensing features	Mandatory (one of)	
TS-001	Touch sensor option		
TS-002	Force (Amps) measurement option		
RS-001	Reflex sensor	Optional	
VC-001	Gripper-mounted video camera	Mandatory	
	No obstruction of the gripper's camera view	Mandatory	
NO-001	Option 1: Second camera has to be installed on the robot's body for navigation purposes		
NO-002	Option 2: A special DOF removes the object from the view		
NO-003	Option 3: Special physical arrangement (e.g. "dog's mouth" configuration)		
	Robust gripper[1]	Mandatory	*See text below*
RG-001	Long fingers		
RG-002	Wide span of fingers		
TM-001	Training mode	Optional	
	Joints position sensing	Optional	
JP-001	Absolute position		
JP-002	Relative position		
	Safety features	Optional	
SF-001	Slow motion		
SF-002	Auto stop if an obstacle sensed		
SF-003	IR obstacle sensors mounted on the arm		
SF-004	Force feedback sensing		
SF-005	Safe mechanical design		

[1] These recommendations are applicable to mobile service robots, but might not be relevant to trainable industrial robots working in closely guarded industrial settings where position sensing and motion can be precisely controlled. See more about this in the text of the corresponding section.

3 Touch sensing

The arm should have a way to detect the moment when the fingers have touched an object. This is needed to stop the motor before the stalling current has caused damage to the motor.

There are two typical ways to implement touch sensing:

1. Force measurement: sense the increase of Amps on the fingers' motor (the motor's stall current will be typically higher than the operating current)
2. Touch sensing: use a special touch sensor on the fingers

4 Object sensing (reflex sensor)

This is optional, but recommended: IR sensor on the gripper.

The sensor tells when an object is detected between the fingers (when the object crosses the IR ray between the fingers). Otherwise, a computer vision technique will need to be used which is a less reliable approach.

5 Video camera mounted on the gripper

The arm should have a video camera mounted on the gripper. The camera is used to control the arm's motion through visual servoing algorithms. Mounting the camera on the arm simplifies computer vision system as compared to a body-mounted camera.

6 No obstruction of the gripper's camera view

This requirement is optional if the robot has two cameras (one on the robot's base for navigation, one on the gripper for object manipulation); this is mandatory if the robot has just a single camera mounted on the gripper.

After an object has been grabbed, the gripper's camera view is typically obstructed by the object. So, it is impossible to visually navigate using the camera mounted on the gripper while an object is kept in the gripper.

As one of possible solutions to the problem, the arm might have a degree-of-freedom which allows removing the object from the view of the gripper's camera while still keeping the object in the arm.

Also, a special mechanical arrangement of the camera and the fingers can be used to ensure that the object does not obstruct the view (for example, "a dog's mouth arrangement").

7 Robust gripper

The general requirement for the design of the gripper is to simplify to job of the object sensing and localization system as much as possible.

Note that the suggestions below might not be relevant to trainable industrial robots as much greater precision of sensing and motion can be achieved in the closely controlled environments typical for industrial installations.

Below are recommendations for *a mobile service robot* or a *mobile personal robot*:

1. Long fingers
2. Wide span of fingers

The fingers on the arm should be long enough and the span of the fingers should be wide enough to allow for incorrectness of detection of object's position and robot's ego position.

8 Training mode

This is optional as there are other ways to achieve the same goal. The arm should have a force-sensing mode in which a user can move the arm by hand to show a certain motion sequence.

9 Position of joints

The arm's controller shall provide a way to read the absolute positions of the joints (optional) or at least relative positions of joints (mandatory).

10 Safety requirements

As robot training requires close interaction of a human trainer and a robot, the robot should be inheritably safe.

The forces applied by the arm should not be too high to cause injuries. Ideally, the arm's controller should have force control logic and/or be able to use IR proximity sensors mounted on the arm for sensing humans/obstacles. This is optional if the arm is not powerful enough to cause injuries.

Useful safety features (all optional, but recommended):

1. Slow motion (to give time to people to react to an unexpected motion)

2. Auto stop if an obstacle sensed:
    a. Option 1: IR proximity sensors mounted on the arm
    b. Option 2: Via force feedback sensing on each of the motors

3. Safe mechanical design which limits the maximum forces applied

The general rule is "the safer the better".

11 About Skilligent

Skilligent's flagship product is a trainable control system for autonomous robots such as mobile service robots, UGV, UAV or AUV. The software enables the robots to learn new behaviors, tasks and skills by observing how human operators accomplish the same tasks. A robot vision system, a part of the package, reliably recognizes objects, landmarks and gestures under real life conditions. The vision system enables the robots to visually navigate, control a manipulator and socially interact with the users.

http://www.skilligent.com