COORDINATION OF PLATFORM AND MANIPULATOR IN TELEROBOTICS

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Abstract: In this article introduction to mobile manipulation problematic is presented, along the few issues which have to be taken into account in order to build complex mobile manipulator such as stability, coordination and obstacle avoidance.
Mobile platform and manipulator forms two subsystems of mobile manipulator and these subsystems have to cooperate in some kind of way. There are three types of cooperation between mobile platform and manipulator.
Two methods for stability measure are briefly described, Zero Moment Point method and Force-Angle Stability Margin Measure method. As a representative of methods used for obstacle avoiding, Artificial Potencial Field is described. I also present the idea of intelligent telerobotic system.

Keywords: platform, manipulator, mobile manipulator, stability, control, telerobotics

1. MOBILE MANIPULATOR AND TELEROBOTICS – BASIC CONCEPT

We all are getting used to the idea that robots are becoming inseparable part of our lives. First stage was using industrial robots in big automobile factories. Now we can see robots arms used in medicine, in food and packing industry. Manipulators are often used for their precision and speed as assembly robots. After that mobile robots become very popular. They have larger workspace then manipulators but are limited only to moving. Therefore by combining manipulator and mobile platform we can get a mechatronic system with high precision manipulation arm with almost unlimited workspace (it's limited only by environment). These systems are called mobile manipulators and their usage is unlimited. It's only matter of proper construction. Mobile manipulators can by used as inspection robots, service robots, as fire fighters or household helpers, etc. Talking about helpers, mobile manipulators are very often used in bomb squads for eliminating bombs which rapidly decrease possibilities of injuries even death. These "bomb squad robots" are typical example of systems called telerobots or teleoperators. Telerobot is mechatronic system, which is controlled remotely by human operator and provides him visual information about environment the robot is operating in. Operator can interact with environment through telerobot on long distances. Telerobots are not autonomous on control level and can be autonomous on power supply level. This concept is very effective since there are no requirements on robot intelligence, which also means that these robots are cheaper then intelligent ones. On the other hand they require human operator.

As is obvious, telerobots can be manipulators as well as mobile platforms or combination of both - mobile manipulators as can bee seen on figure 1.
There are many problems which have to solved in controlling robots. They are different for platforms and manipulators. In this article mobile manipulator problematic is discussed, of course not everyone since there are many of them, and not everyone refer to telerobotic mobile manipulators. Issues present here are cooperation, stability and obstacle avoidance.

Fig. 1 Mobile manipulator developed by company iRobot

2. PLATFORM AND ARM COOPERATION

Mobile manipulator is combined of its two subsystems. Mobile platform and manipulator. These subsystems have to cooperate in some kind of way with each other. There are 3 types of cooperation (U.M. Nassal, 1994).

Loose cooperation is characterized by two separated subsystems with no common control. Movements of platform and manipulator are executed sequentially because there is no control to ensure collision free motion execution. Each subsystem has own motion planner. The platform serves for transporting the manipulator and increases the robot's workspace that way. This kind of cooperation is suitable for moving the manipulator to spatially distributed assembly stations or to move it at an assembly station into a position that allows more efficient manipulation of an object. Kinematic redundancy has to be regarded only when a platform position has to be computed. The task of motion planning, an essential problem for autonomous systems, can be easily decomposed into two separate tasks. Furthermore, there is no limitation for the number of manipulators mounted on the platform that can be supported that way.

Complete cooperation. For the complete cooperation of a mobile platform and a manipulator, the two subsystems are regarded as one system. The mobile platform increases the DoF of the manipulator. Both systems always move together for positioning the end point of effector. There are two different approaches to the resolving of kinematic redundancy for completely cooperating systems (Baker and Wampler, 1987) the first one is path inversion, where the complete end-effector trajectory is a priori known and transformed into joint motions by an off-line optimization procedure. Since this scheme is not appropriate for sensor-controlled manipulation tasks, another method used is local inversion. This scheme exploits only local properties of the end-effector motion, such as the end-effector velocity, and derives joints velocities using a local optimization procedure.

Transparent cooperation is designed to combine the advantages of the loose and complete cooperation and to avoid the named disadvantages for autonomous systems. The main idea is, that in a first step the end effector motion is made independent from the vehicle motion, i.e. if the vehicle is moving, the end effector position is not affected. Thus, the vehicle motion is transparent to the end effector. More formal, the platform motion does not result in an external motion of the manipulator but merely in an internal motion, i.e., the configuration of the manipulator is modified. To achieve this, a kinematic decoupling scheme has to be established, that is working in the manipulator control loop to compensate for the platform motion. The second step is to control the platform in such a way, that the manipulators are enabled to perform their tasks and their configuration is optimized with respect to some task specific cost function. This type of cooperation supports the usual way of transporting the manipulators by moving the platform as well as a coordinated motion with the platform continuously supporting the manipulators. Motion planning for the manipulators can be performed using known schemes. If the platform has to be moved to enlarge the workspace of the manipulator, this can be done in parallel to the manipulator motion and in consideration of obstacles for the platform. Several manipulators can be mounted on the platform correspondingly to the loose cooperation.

3. STABILITY

Mobile manipulators are and will be often use for object manipulation. Therefore issue of mechanical stability becomes really important. Possible instability is caused mainly by manipulator, since mobile platform is statically and in most cases also dynamically stable. Let's assume that mobile manipulator was designed as statically stable, possible tip over of the robot can be caused by fast manipulator moving, fast cornering and manipulation with heavy loads or moving on sloping surface. Of course we can not forget influence of external forces acting on mobile manipulator. It is essential to determine stability margin of the system so stabilizing action can be perform. There are two mostly used methods for determining stability margin. ZMP and Force-Angle stability margin measure.

3.1 ZMP – Zero Moment Point Method.

The principle of this method is in determining position of the point in which the sum of all forces and moments acting on a robot is zero (J. Kim, *et al.,*1994). Therefore ZMP. This zero point is examined in the area of stable zone, which is defined as contact polygon between platform wheels and the ground (Fig. 2). If we want to take into account external forces as well, we need to define effective zone of stability (Fig 2). This is smaller then a stable zone due to activity of the external forces. The difference between zone of stability and effective zone of stability should be larger then the stability changes caused by external forces. Result is that the mobile manipulator is stable if position of the ZMP is inside of the effective zone of stability. Stability margin is then the shortest distance between ZMP and boundary of effective zone of stability.

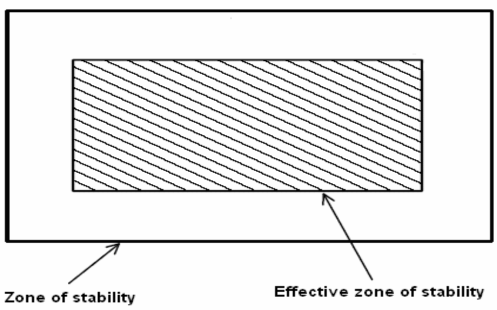

Fig.2. Zone of stability and effective zone of stability

3.2 Force-Angle Stability Margin Measure

This method is based on direction of resulting force acting on robot and normal vector of tipover axis (Rey and Papadopoulos, 1997). Tipover axis is defined as connection line between two contact point of platform and ground. Resulting force with origin in centre of a mass and its projection into plane which is perpendicular to the tipover axis are computed. Then we can compute angle between mentioned projection and normal vector of tipover axis with the same origin in the centre of a mass. If this angle is smaller then a defined threshold value, mobile manipulator can tip over. It is useful to establish also time parameter into the analysis, which means that stabilizing actions will be executed only if stability margin ran under the threshold value for given period of time. This will prevent to execute stabilizing actions after short impulse of stability drop. As a stabilizing action we can understand action as moving platform under the manipulator for better supporting or moving manipulator to home position in which manipulator is acting on platform with zero or very small force. On the figure 3 is simple display of Force-angle stability margin measure principle. Where l_1,l_2 are normal vectors of tipover axis, f_r is projection of resulting force and θ_1, θ_2 are angles which represent stability margin.

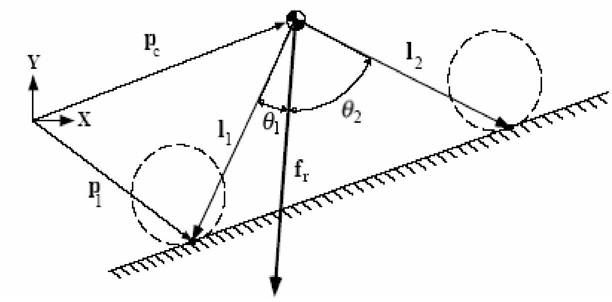

Fig.3. Display of principle of Force-angle stability margin measure method

4. OBSTACLE AVOIDANCE

Detection and avoidance of obstacles is very important part of mobile manipulators control, mainly while moving in unknown environment. Disadvantage of mobile manipulator against simpler mobile robots is that collision free space has to be monitored in 3D and not only in plane in which is mobile manipulator moving. One of the possibilities of detecting obstacles is processing visual information from cameras built on the robot. This approach is more complicated then for example using infrared or ultrasonic sensors. Of course there is still an issue of information fusion. Let’s assume that we are able to measure a distance from each part of a mobile manipulator to the nearest obstacle. Then we can compute bubbles (fig. 4) around these parts representing that way a free space around the robot parts (Brock and Khatib, 1998a, b).

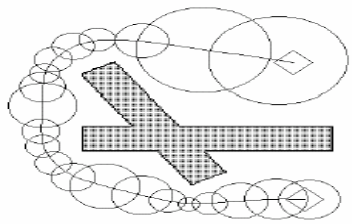

Fig.4. Bubbles representing free space around a robot

For obstacle avoiding its self can be used method called Artificial Potencial Field (APF). The principle is in repulsive and attractive forces acting on each part of a mobile manipulator. Obstacles act with repulsive force as well as beginning of trajectory – Start and end of trajectory – finish acts with attractive force (Krogh, 1984)(Khatib, 1986). The resulting force acting on the mobile manipulator parts will determine the directions of movement. In case obstacle is more complex we have to describe that obstacle with basic shapes and then compute repulsive forces from each part of obstacle. In case of more then one obstacle, resulting force is sum of all forces acting on mobile manipulator part.

5. FUTURE WORK

In my future work I would like to concentrate on developing control for intelligent teleoperator, which means implementing control with obstacle avoiding mechanism at first. Stability margin measure method has to be implemented in order to have stable system even during manipulation with objects. This intelligent teleoperator will help its operator in more comforting control of robot, so operator will concentrate on executing tasks. Mobile manipulator control will recognize obstacle and avoid them automatically. Also stability will be maintained automatically to prevent tipover of the system. I can see this as a big contribution mainly in applications where time is really important and also absolute operator concentration is needed.

6. CONCLUSION

Methods presented here were only briefly discussed to bring basic insight for reader into mobile manipulation problematic. There are more tasks which have to be solved – trajectory generation, movement planning, map creation and others. I presented only three which are essential for intelligent telerobot. Two methods for stability margin measure where introduced along with three types of cooperation between mobile platform and manipulator. Very important part of mobile robotics is obstacle avoidance. Artificial Potencial Field as one of the most used method was presented.

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