CHAPTER 24

WAITER ROBOT: ADVANCES IN HUMANOID ROBOT RESEARCH AT UC3M

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Multiple robotic system are used to develop new tasks as a waiter robot. The most complex kind of robots devoted for these tasks are humanoid ones. This paper is focus on presenting the evolution of the control system applied on the humanoid robot TEO at the Carlos III University of Madrid. There are two main goals to be achieved by this research. The first one is to learn how a humanoid robot can manipulate objects without physical grasping, maintaining the object balance and its own whole-body balance, and to develop an appropriate control system to deal with this specific service application. The operation of the system is supported in the proposal of one simplified robot model that joins both the robot balance and manipulation model and the simplified object balance model. The second objective is to suggest new complex strategies related to balance control taking into account stronger external disturbance.

1 Introduction

The actual world is deeply adapted to humans, as we are the ones living in it. This is why the development of humanoid robots is such a relevant matter, getting rid of the need for adapting the environment. This has other advantages. A robot is mechanically similar to a human and it can carry out similar tasks. However, there are also disadvantages in designing a humanoid robot, apart from the obvious complexity of its building. This is to say, the more resemblance between the humanoid and the human, the more the problems of the later become the problems of the former. One of these problems to be solved is equilibrium.

In this paper we go through the equilibrium control in a waiter robot. Not only do we control the equilibrium of the robot itself, but also the equilibrium of the objects being carried on a tray. This becomes a complex task since it is a non-grasping manipulation. On the one hand, the robot has the ability of sensing if it is losing stability and falling. On the other hand, it has the ability of avoiding the fall of the transported objects. These abilities are intrinsic and instinctive in human beings, but not in robots.

When it comes to equilibrium, we must take into account any influences in the system. It can suffer two types of disturbances (Petrović et al., 2014): the ones caused by the system itself and the external ones. Both types influence the locomotion equilibrium as well as the manipulation equilibrium. It is our job to analyze how they affect the system.

2 Waiter robot

The ‘waiter robot application’ simulates the movement behaviour of a waiter while trying to transport bottles/cups on a tray. There are two tasks for achieving the main target of this application. The first task is focused on keeping the balance of the transported object. During the execution of the application, the objects are disturbed by forces caused by the own movement of the waiter robot. The second task is to control the stability of the waiter robot. During its movement, the humanoid robot ought to be able to avoid falling while it walks. Both tasks, body balance and object balance, must be accomplished in the same control period, imposing a strict manipulation and locomotion coordination (Fig. 1).

The waiter task is bio-inspired in the real world. To define this application, the morphological aspects related with a human waiter were taken into account. So, like human beings use their own proprioceptive sensors to detect their equilibrium state, a robot also uses its sensor for locomotion tasks. These sensors are inertial, position and force/torque sensors. Besides, the sensors are necessary to develop manipulation tasks. Then, it is important to sense the arm’s state to control the pose of the drink tray.

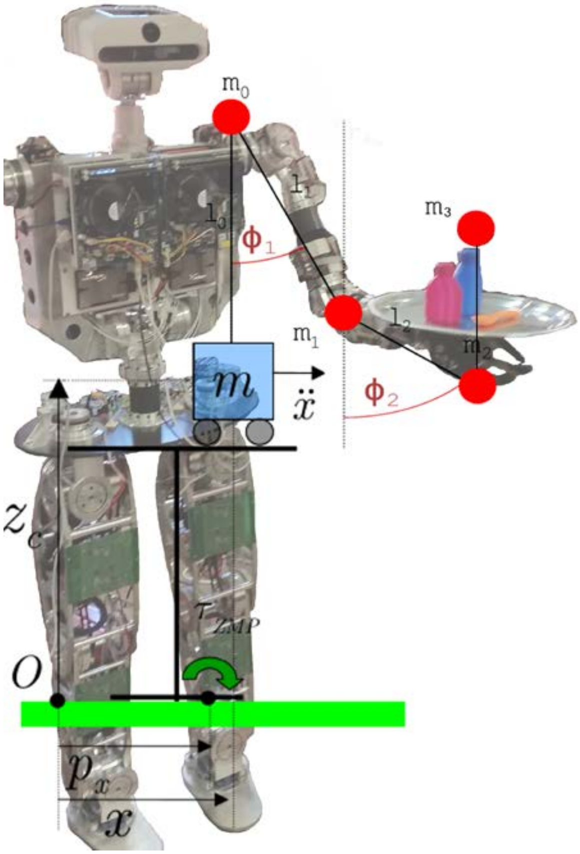

Fig. 1. Simplified mathematical model generated for balance control.

3 Locomotion equilibrium control

Several authors have been researching balance in bipedal robots since years ago, and this topic has suffered major development in recent years. Some of them have studied the forces acting on humanoid robots (Sardain & Bessonnet, 2004) and others have even developed balance strategies (Stephens, 2011). The stability control can be designed in so many different ways. For instance, using the Zero Moment Point as the reference point for stability, and implementing a ZMP balancing control (Vadakkepat & Goswami, 2008).

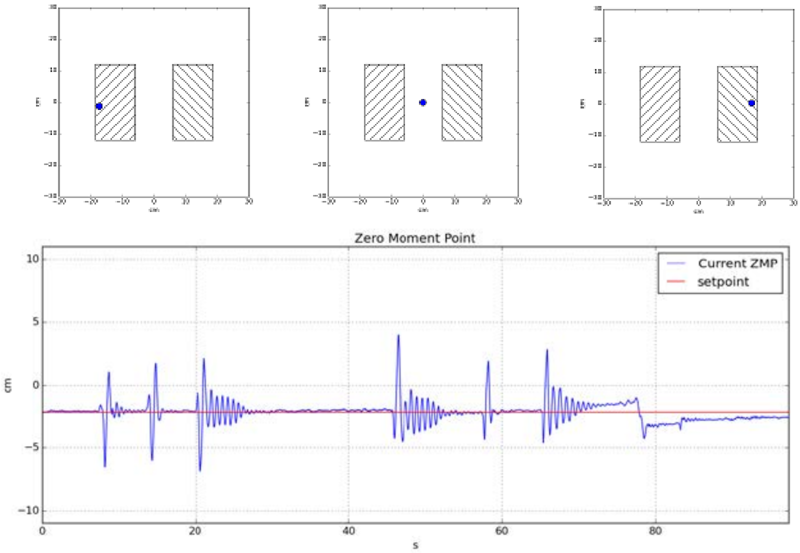

Fig. 2. Computation of ZMP for different situations and results of the stabilization control applying ankle strategy.

In the humanoid robotics research group, it is currently developing an equilibrium control for our humanoid robot TEO, using inertial and force/torque sensors, and based on the same principle regarding the ZMP. First of all, we use the data obtained through the sensor to compute the Zero Moment Point (Fig. 2) using the cart-table model (Kajita & Espiau, 2008). Then, the current ZMP and the desired ZMP are compared in a PID controller, which consequently offers an output. This output is used as the velocity input, in deg/s, to be sent to the motors of the robot’s ankles. Finally, thanks to this velocity command, the rotation of the ankles counteracts the leaning of the robot avoiding its fall.

This strategy is implemented both in the sagittal and the frontal plane. However, it is slightly different for the frontal plane, as the system becomes a double-support inverted pendulum instead of a single-support one. For this case, the same procedure is followed but the velocity command is sent to the ankles and to the hip joints, trying to maintain the torso straight and then returning to the stability position.

4 Manipulation equilibrium control

To model the behaviour of the bottle or drinks on the tray, a linear inverted pendulum model (LIMP) is used. In this case, the goal is to maintain stability and the pendulum model is a good option because there is a large friction force between the bottle and tray. Due to a non-slip material in the tray, it is possible to affirm that there is no linear movement between the bottle and the tray. Only, rotational movements will be generated. For this reason, the LIPM model was chosen and not the cart-table as in the case of the stability of the whole-body humanoid robot. Therefore, the control algorithm mainly is focused on variations of the rotation’s angle of the bottle to indicate its stability.

In this case, the bottle does not rest on a single point, i.e., the bottle rests on a surface. Then, it is possible to use the same balancing robot strategy to define the state of stability for the bottle. That means ZMP can be used as indicative. Thus, when the projection of the sum of the forces/torque in the centre of mass of the bottle exceeds the support surface with the tray, this one will fall. Therefore, it is important to develop a complex 3-D kinematics configuration with a special non-grasping device to keep the balance of the bottle over the tray (Balaguer et al., 2006).

5 Advances on the development of the waiter robot

We aim to achieve a equilibrium control during locomotion. Nevertheless, currently we are focusing on static equilibrium, not involving locomotion yet. That will be the next step once the static control is successfully implemented. On the other hand, static equilibrium is related to manipulation as they influence each other, so it has to be taken into account.

The already implemented equilibrium control works correctly when counteracting small disturbances. However, when a strong disturbance affects the robot, the ankles reaction is not enough for avoiding the fall. Here is when the hip and step strategies come into action. Firstly, the limits of the ankle strategy must be determined. We can set these limits mathematically or by experimentation and the aim is to be able to anticipate if the ankles reaction will be enough for avoiding the fall or not. Once this is achieved, the same must be done in order to check if the hip strategy is enough or the system needs to jump into the last option: the step.

The hip strategy is based on the same principle as the ankle strategy, with the slight variation that the velocity command is also sent to the hip joint. The motion of the whole torso provides a stronger counteraction, which increases the options of stabilization. The step strategy can be implemented in many different ways (Assman, 2012), but the gist of it is to perform a step in order to change the support region and thus recover stability. Sometimes the gait planning is done according to the ZMP (Arbulu & Balaguer, 2007), which is a big advantage in order to join the locomotion process and the step strategy.

Furthermore, if more effective ways of keeping balance are wanted, we can dig into more complex strategies. The control of many other joints of the robot can add an extra point in the equilibrium control. Bending the knees, for instance, is useful for this purpose. Moreover, moving the arms back or forth helps keeping balance by changing the center of gravity, but this can be implemented only in one arm as the waiter robot is using the other one to carry bottles or cups.

Finally, we must also consider the influence of the manipulation process in the equilibrium control and viceversa. The motion required to avoid the fall of the objects being carried on the tray provokes instability in the body balance as well as the whole body equilibrium control affects the manipulation control. This is to say, the manipulation process must be taken into account in the equilibrium control and the effects of this equilibrium control will influence the manipulation system.

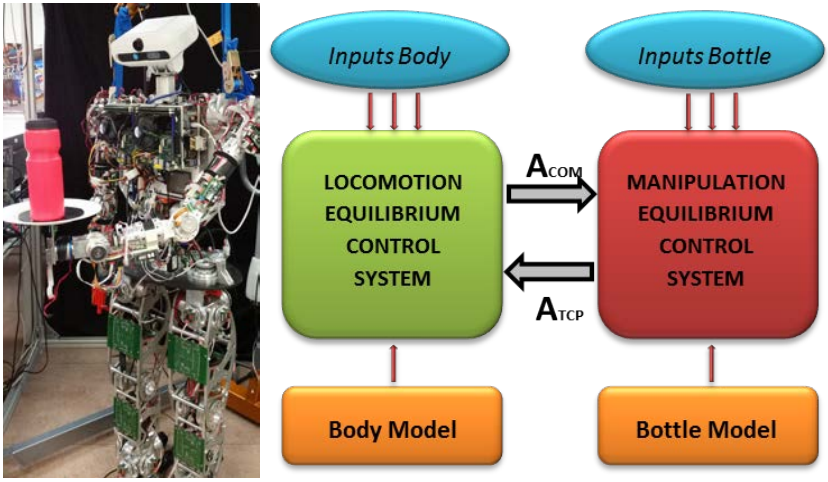

Fig. 3. Control and coordination scheme of the whole body balance.

6 Conclusions

The development of applications of the real world in humanoid robots implies the integration of basic research topics in this field of robotics. Gait planning (Arbulu & Balaguer, 2007) or multi-contact body balance (Vukobratović & Borovac, 2004) are examples of this basic research used to develop more complex tasks regarding equilibrium and locomotion. In the case of manipulation, classic research is focused on how objects can be grasped. In this paper the application of a waiter humanoid robot has been presented. This application combines classic equilibrium control techniques with a special case of manipulation. Non-grasping manipulation of objects implies to face the treatment of the problem in a different way. In this case, the main problem is to keep the object in equilibrium on a tray. So, all parameters related with body balance have been translated to determine the object balance. Thus, facing both balance problems in an integrated way increases exponentially the complexity of balance control in this application.

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