Chapter 8

Conclusions

This thesis describes the control, development and construction of a biped robot. The biped robot has features such as small size, light weight and low-cost. The light weight property helps to achieve a faster speed at walk. At first, a biped robot's prototype with 6 degrees of freedom was developed, but it has not implemented the links to produce laterals movements, instead of that, this prototype used an inverted pendulum as a lateral control actuator, but this actuator increased the instabilities during the robot's walking. However, this first prototype brings important experiences on the mechanical design, and also was useful to test a *walking sequence algorithm*, the so-called periodic function approach [12]. A Matlab program to simulate the robot's walking was implemented to find the position's sequence for the robot's real-time walking.

In the second robot prototype, "Dany walker" the degrees of freedom were increased to 10. Thus, there were four new DOF with regard to the first prototype. Two at the hip and two at the ankles, allowing the robot's structure to have laterals movements and facilitate the balance control means those mechanical modifications. These mechanical modifications have a positive impact on the robot's performance at walk. Improving the results of the balance control, means the four new lateral motors which demonstrate be very effective to achieve balance. Thus, the pendulum idea to balance the biped robot was complete abandoned.

This thesis propose, an *incremental fuzzy PD controller* based on the ZMP criteria to implement the balance control of a biped robot. From the experiments, it is possible to observe an effective balance controller's performance for a x-direction impulse (Chapter 6, figure 6.2). The response was fast (approximated 2 seconds), until the controller reach a ZMP value near to zero. This feature allows the biped robot to gain stability even during walking (figure 6.7), maintaining the ZMP always inside of the support polygon.

The *incremental fuzzy PD controller* algorithm demonstrated to be appropriated for the biped robot's balance control, and computationally economic. The algorithm runs in a low cost PIC microcontroller with a memory of 2 kilobytes . The algorithm was successfully tested in real-time in the "Dany walker" biped robot, videos showing the tests are available at: http://www.inf.fu-berlin.de/~zaldivar.

With regarding to the performance of the *walking sequence algorithm* used in this thesis, is possible to observe a smooth transition between the *single support phase* and the *double support phase* (figures 6.12 and 6.15). That was possible because the *walking sequence algorithm* drives smoothly the link's velocities, and even reached velocities near to zero or even of zero at the end of the walk phases [15]. This advantage of the algorithm allows the robot to gain stability during violent impacts, such as those produced by the motors velocities during *single support phase*. The *walking sequence algorithm* implemented in this thesis also can potentially be used in other biped robot's structures with a similar dynamic to generate a biped gait. This algorithm was programmed using a PIC "C" compiler and tested in a PIC 16C873 at the "Dany Walker" biped robot.

The bipedal robot designed in this thesis is part of a biped robot design project which is being developed at the Freie Universität Berlin.