# Combining visual servoing and walking in an acceleration resolved whole-body control framework

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Don Joven Agravante, François Chaumette
Inria Rennes - Bretagne Atlantique, France
don-joven.agravante@inria.fr, francois.chaumette@irisa.fr

## Abstract

This work aims to create a solution to executing visually guided tasks on a humanoid robot while taking advantage of its floating base. The base framework is an acceleration-resolved weighted Quadratic Programming approach for whole-body control [1]. This allows us to define different tasks for different control points (i.e., Center of Mass/CoM, hand, gaze) on the robot while respecting constraints (i.e., actuation limits, contacts). In this work, we create visual servoing tasks - specifically a Position-Based Visual Servoing (PBVS) task for the right hand and an Image-Based (IBVS) task for centering the target in the image space. The formulation used is:

$$\ddot{\mathbf{e}} = \mathbf{L_e J_p \ddot{q}} + \mathbf{L_e \dot{J}_p \dot{q}} + \mathbf{\dot{L}_e J_p \dot{q}},$$

which is consistent with the acceleration resolved approach for a task vector $\mathbf{e}$, where $\mathbf{L_e}$ is the interaction matrix from visual servoing literature, $\mathbf{J_p}$ is the robot Jacobian of a control point $\mathbf{p}$ and $\mathbf{q}$ are joint positions. The formulation can be used for both PBVS and IBVS simply redefining $\mathbf{e}$ and the corresponding $\mathbf{L_e}$. For walking, we use a walking pattern generator (WPG) similar to [2]. This generates a dynamically consistent CoM motion along with the future footstep locations and timings of foot contact transitions. However, since the WPG is solved separately, we will need a way to couple the WPG reference velocity and the visual servoing tasks. A simple but effective method is setting:

$$\dot{c}_{\text{xref}} = k_v(t_{\text{xPBVS}}), \qquad \dot{c}_{\text{yref}} = 0, \qquad \dot{\theta}_{\text{ref}} = -k_\theta(\theta_{\text{gaze}}),$$

where the WPG input reference velocities are $\dot{c}_{\text{xref}}, \dot{c}_{\text{yref}}, \dot{\theta}_{\text{ref}}$, while $t_{\text{xPBVS}}$ is the translation part of the hand PBVS task corresponding to the $x$ axis of the WPG frame (local frame on the robot), $\theta_{\text{gaze}}$ is the yaw angle of the gaze frame relative to the current WPG frame and $k_v, k_\theta$ are gains to tune. The idea is that the hand PBVS will guide walking forward. Walking sideways is not used. The orientation is guided by the gaze IBVS. Finally, note that bounds are needed for $t_{\text{xPBVS}}$ and $\theta_{\text{gaze}}$ that are used in the coupling. When a bound is exceeded, we use: $\mathbf{e}' = \frac{\mathbf{e}}{\max(\mathbf{e})}$ where $\mathbf{e}$ is the unbounded error, $\max(\mathbf{e})$ is the largest limit violation and $\mathbf{e}'$ is the result used. This preserves the vector direction. We validated this approach with simulations using the HRP-4 robot. Screenshots are shown below:

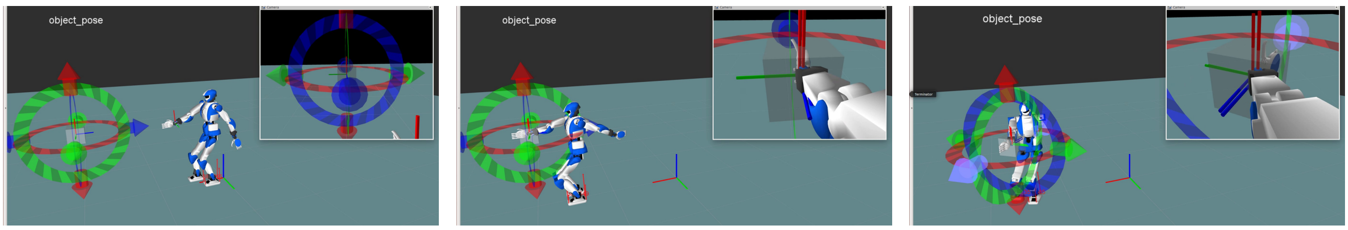


Figure 1: Example screenshots of a simulation of positioning the hand and gazing the target

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## References

[1] J. Vaillant, A. Kheddar, H. Audren, F. Keith, S. Brossette, A. Escande, K. Bouyarmane, K. Kaneko, M. Morisawa, P. Gergondet, E. Yoshida, S. Kajita, and F. Kanehiro, "Multi-contact vertical ladder climbing with an HRP-2 humanoid," *Autonomous Robots*, vol. 40, no. 3, pp. 561–580, 2016.

[2] A. Herdt, H. Diedam, P.-B. Wieber, D. Dimitrov, K. Mombaur, and M. Diehl, "Online walking motion generation with automatic footstep placement," *Advanced Robotics*, vol. 24, no. 5-6, pp. 719–737, 2010.