Soft Legs Project
Matlab/Casadi/Robotran Procedures
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The present guide will help in understanding the basic operations needed to run the optimization problem solution and the principal components analysis of the Soft_Legs project done by Gian Maria Gasparri [1].

Main Folder Structure

The overall procedure can be run **step-by-step** from the *Main_SoftLEGS.m* script inside the folder named `/Main Scripts SOFTLegs`. The folder contains the following files:

- `/Final_Maps`; in this folder the file generated after the Principal Components Generation procedure, i.e. the Matlab file named `set_SVD_TH.mat` will be saved in order to be loaded from the other procedures.
- `/From_dataset_to_PCs_and_CMs`; this folder contains all the file necessary to analyze the trajectories generated from the Robotran Simulations and all the relative figures obtained. It generates also the maps file saved in the above folder.
- `/NO_ZMP_dataset_from_matlab_to_cpp`; in this folder there are all the files needed to convert the datasets into header (.h) files used by the *ROS* nodes and GUIs.
- `/Robotran_Traj`; the trajectories to simulate the walk will be saved inside this folder from the runOpt() procedure.
- `/ZMP_NO_Comparison`; this function generates the results for the Zero Moment Point (ZMP) walking, starting from the simulations data, but apparently gives incompatible data. However, it is only needed to compare the two walking strategies and **can be not considered** for the optimal walking only.
- `Planar_Legs_Soft-Robotran`; contains all the Robotran project to be copied into the Robotran directory (usually in `/Documents/MBProjects`) in order to launch the Optimization procedure.

- `SoftLegs ROS Workspace`; this folder contains the overall ROS framework to use the Soft_Legs GUIs and other utilities. Just copy all the `/src` folder inside the `/catkin_ws` workspace and compile it. **NOTE** during the compile process you will probably encounter small errors due to miss packages. After fix them alla the nodes will be ready to go! Please refer to [2] for an overview of the GUIs.

- *Main_SoftLEGS.m*; main Matlab scritp that runs all the procedures, *runOpt, runMaps, runConv* and *runTraj* detailed below.

In the following each part of the procedure is briefly described.

Robotran Simulations & Optimization (runOpt)

For this procedure CasADi (v3.1.1 available in this repository) should be installed into your PC. This procedure also requires that you have copied the Planar_Legs_Soft project into the Robotran folder. Inside the archive, in `/workR`, you will find a file named

optimal_Kel_walk_experiments_Multi_Sims.m

Launching the above script, multiple simulations of the walking task will be run, and an optimal problem will be solved in order to minimize a cost index function according to [1].

The inputs of the simulations are the range of velocities (`walkS`) that you want to simulate and the foot high (`stepH`) that you want to use during the simulations. In addition you can pass a third parameter that is the step length (`stepL`). All these parameters are passed as global variables.

The results of the simulations will be saved into a new folder created inside the `/workR` directory (named `fldName`) and will be saved as

`Whole_1_#.mat`

`succ_cases_#.mat`.

where `#` is the total number of simulations. For a detail of each cell of `Whole_1_#.mat` have a look inside the *save_res.m* script.

Now, in order to run the remaining procedures, you have to **manually** copy these two files inside the `/dataset` folder in `/From_dataset_to_PCs_and_CMs`.

Principal Components Generation (runMaps)

In this part of the code the principal components (PCs) analysis and the component maps (CMs) are computed. The main script to be run is named as the folder, i.e.

From_dataset_to_PCs_and_CMs.m

This script will ask you to choose among the available datasets inside the `/dataset` folder, then it automatically loads the data chosen. The data must be in the format `Whole_1_#.mat` and `succ_cases_#.mat`, previously obtained from the runOpt() procedure.
The inputs parameters are the number of Principal Component to be used (`N_PCs`) and the order of the polynomial that fit the coefficents of the maps /`polyDegree`). These parameters are passed as global variables.
The results of this procedure are stored inside the `/Final_Maps` folder and in the Matlab data files named

`set_SVD_TH.mat`

In addition, this procedure generates a function that allows to compute the trajectories starting form the component maps, given a desired velocity and a foot high parameter. The function is named

Original_From_CM_To_Traj_TP.m

For a detail of each cell of `set_SVD_TH.mat` have a look inside the *SVD_Analysis.m* script.

ROS .h Files Generation (runConv)

Move into the folder `/NO_ZMP_dataset_from_matlab_to_cpp` and run the two files named

Generate_NO_Optimal_Dataset_SoftLegs_GUI.m

Generate_ZMP_Dataset_SoftLegs_GUI.m

(**NOTE** that there are no (not correct!) procedures to obtain the data loaded for the ZMP walk case, thus they are the same used by G.M.Gasparri for the original work). The input parameters are the results of the *runOpt* procedure, i.e. `Whole_1_#.mat` and `succ_cases_#.mat`, stored inside the /dataset folder and automatically loaded from the script, after a display request. The output is the header files named

Optimal_Dataset_NO.h

These two files are used inside the *ROS* nodes `optimal_walk` and `zmp_walk`, respectively.

Robotran Trajectories Generation (runTraj)

The last procedure of the main script allows to generate an optimal motors trajectory, starting from a desired velocity (`v`) of the Soft_Legs, a foot high

(`fh`) a foot length (`fl`) and the component maps (CMs) to be used (`setName`) obtained with runMaps().

This procedure automatically loads the Matlab file containing the component maps named `set_SVD_TH` since it is passed as parameter for the runTraj() function.

The trajectory generation returns the optimal motor positions obtained with the *Original_From_CM_To_Traj.m* script generated by the runMaps(). Furthermore, numerical velocities and accelerations are computed using the sample time computed as in [1]. All these data are store in a file named `Trajectory.mat` saved inside the `/Robotran_Traj` folder.

References

1) G.M.Gasparri, S.Manara, D.Caporale, G.Averta, M.Bonilla, H.Marino, M.G.Catalano, G.Grioli, M.Bianchi, A.Bicchi and M.Garabini. *Efficent Walking Gait Generation via Principal Component Representation of Optimal Trajectories: Application to a Planar Biped Robot with Elastic Joints*. IEEE Robotics and Automation Letters. January, 2018.

2) G.M.Gasparri. *Soft_Legs_Easy_Handbook*.