Creating an Optimization

OpenSim Developer's Workshop | October 2009

Outline

1. Optimizer class in SimMath

- What is an optimization problem?
- What is the **`OptimizerSystem`** class?

2. Extending the `OptimizerSystem` class

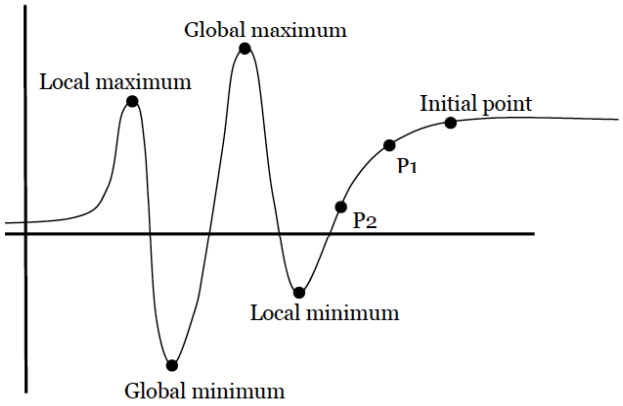
- Define a subclass for our optimization
- What do I pass into the constructor?

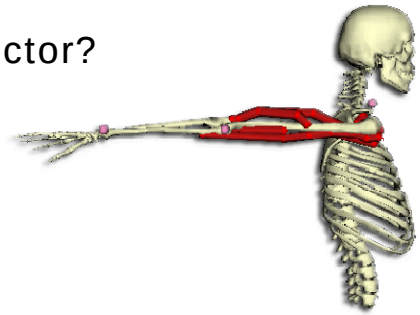
3. Writing the main()

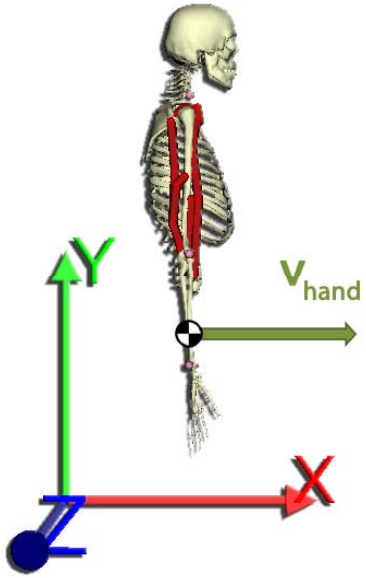
- Set controls with initial guess
- Set bounds on the controls
- Creating the optimizer

4. Writing the Objective Function

- Creating the integrator and manager
- Finding the objective value



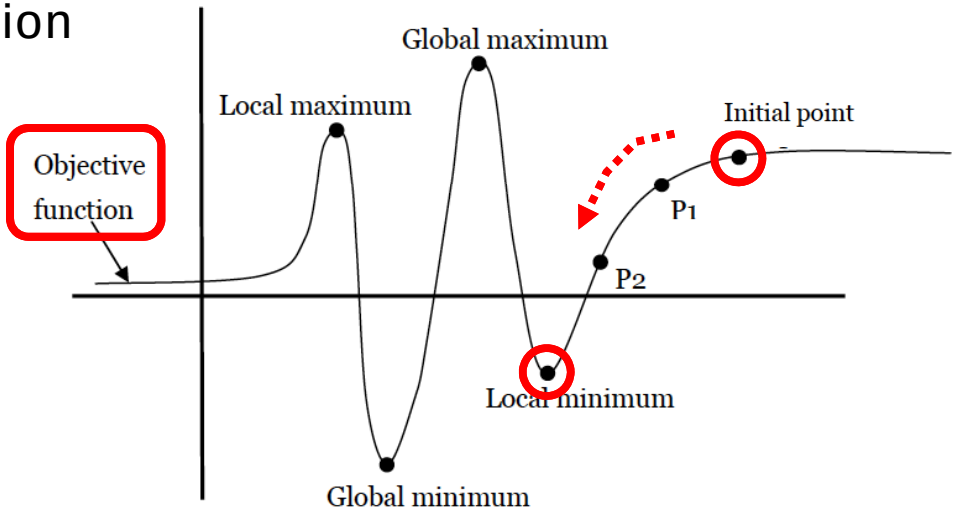




What is an optimizer?

The **`Optimizer`** class searches for points which are a minimum of an user-defined objective function.

- Define your objective function
- Start with initial guess
- Iterate to find points that reduce the objective
- Terminate when objective function stops decreasing



Notes:

- May not find global minimum, thus solution can be sensitive to your initial guess.

- To find the maximum, just multiply the objective function by -1.

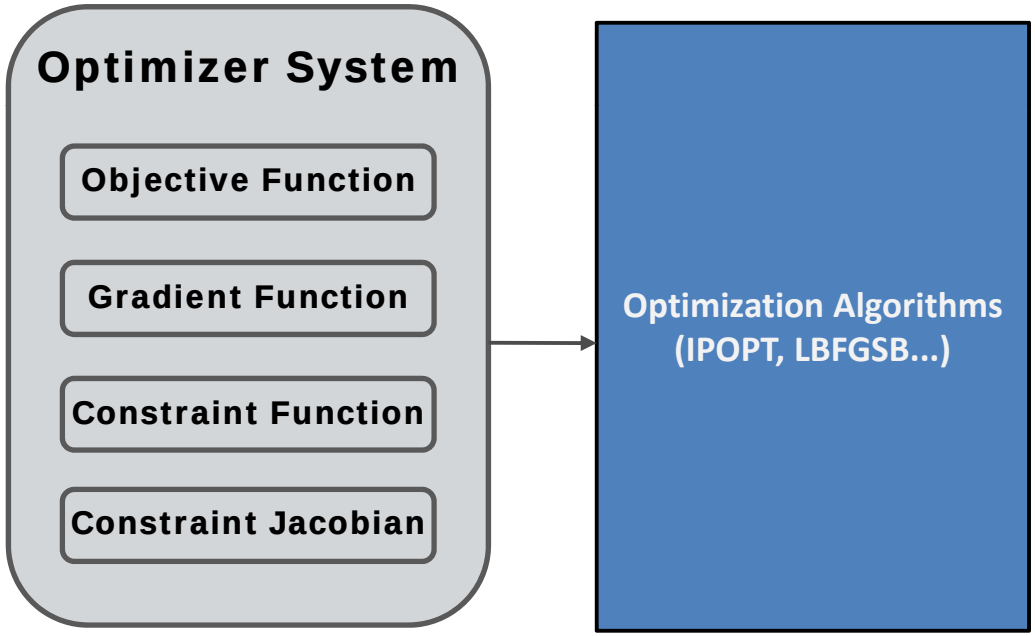
The OptimizerSystem class

OptmizerSystem is an abstract class which has methods for computing:

- The **objective** function
- The **constraints**
- The **gradient** function
- The **constraint Jacobian**

- It provides an interface to multiple optimization algorithms.

- To use **OptimizerSystem** we need to define our own concrete subclass...



Extending the OptimizerSystem class

For each new optimization problem, we need to extend **OptmizerSystem** into our own subclass, like **ExampleOptimizationSystem**

```
class ExampleOptimizationSystem : public OptimizerSystem {
   public:

   /* Constructor class. Parameters accessed in objectiveFunc() class */
   ExampleOptimizationSystem(int numParameters, State& s, Model& aModel):
      numControls(numParameters), OptimizerSystem(numParameters),
      si(s), osimModel(aModel){}

   /* The objectiveFunc() class will go here. */

   private:
      int numControls;
      State& si;
      Model& osimModel;

};
```

Writing the `main()`...

In this section of the **`main()`**, we initialize the optimizer, set the bounds on the controls, and provide an initial guess for the controls.

```
// Number of controls will equal the number of muscles in the model
int numControls = 6;

// Initialize the optimizer system we've defined.
ExampleOptimizationSystem sys(numControls, si, osimModel);
Real f = NaN;

/* Define and set bounds for the parameter we will optimize */
Vector lower_bounds(numControls);
Vector upper_bounds(numControls);

for(int i=0;i<numControls;i++) {
   lower_bounds[i] = 0.01;
   upper_bounds[i] = 1.0;
}
sys.setParameterLimits( lower_bounds, upper_bounds );

// set the initial values (guesses) for the controls
Vector controls(numControls);
controls[0]  = 0.01; controls[1]  = 0.01;
controls[2]  = 0.01; controls[3]  = 0.01;
controls[4]  = 0.01; controls[5]  = 0.01;
```

Writing the `main()`...

In this section of the **`main()`**, we create an **`Optimizer`**, specify settings, and run the optimizer!

```
try {
    // Create an optimizer. Pass in our OptimizerSystem
    // and the name of the optimization algorithm.
    Optimizer opt(sys, SimTK::LBFGSB);

    // Specify settings for the optimizer
    opt.setConvergenceTolerance(0.05);
    opt.useNumericalGradient(true);
    opt.useNumericalJacobian(true);

    // Optimize it!
    f = opt.optimize(controls);
}
catch(const std::exception& e) {
    std::cout << "Caught exception :"  << std::endl;
    std::cout << e.what() << std::endl;
}
```

Writing the Objective Function

Define **objectiveFunc** as a public member of **ExampleOptimizationSystem**

Input: muscle controls (i.e., parameters we want to vary)
Output: real number measuring performance (i.e, hand's forward velocity)

```
int objectiveFunc(const Vector &newControls, const bool new_coefficients,
   Real& f ) const {

   // make a copy of out initial states
   :State s = si;

   // Access the controller set of the model and update the control values
   ((ControlSetController *)(&osimModel.updControllerSet()[0]))
      ->updControlSet()->setControlValues(initialTime, &newControls[0]);
   ((ControlSetController *)(&osimModel.updControllerSet()[0]))
      ->updControlSet()->setControlValues(finalTime, &newControls[0]);

                                    .
                                    .
                                    .
   /* Calculate the scalar quantity  for the optimizer to minimize
   *  In this case, we're maximizing forward velocity of the
   *  forearm/hand mass center so compute the velocity and
   *  just multiply it by -1.

   // FILL IN THE OBJECTIVE FUNCTION HERE!!!
   // f = ???;
```

Running the Optimization…