A Bioinformatics Approach to Model and Analyze an Industrial Radiation Therapy System with Respiratory Compensation

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Abstract:

This paper presents our industrial experience on Bioinformatics. We define one-dimensional model with latency (delays) and acceleration using mixed discrete and continuous (hybrid) dynamics of an industrial radiation therapy system with respiratory compensation using Open Modelica tool. We then investigate and analyze the model with several tumor movement trajectories.

Keywords: Bioinformatics, radiation therapy, respiratory compensation, Open Modelica

1. INTRODUCTION

Bioinformatics is the application of the concepts and methodologies from *Computer Science* in Biology and Medicine. In this paper, we present our industrial experience on Bioinformatics, i.e modeling of radiation therapy system. The goal of radiation therapy is to give as much dose as possible to the target tissue, and minimize impact on healthy tissue. Many different techniques are used to achieve it on moving targets[1]. We model and analyze a radiation therapy system with respiratory compensation consisting of a HexaPOD couch[2] with 6-degrees movement (3xtranslational + 3xrotational), a tracking camera, a marker (markers) and a controller using Open Modelica tool[3,4]. The model presented in this paper extends the previous models[5,6,7], which has been found to be insufficient to completely determine the adequacy of system to compensate respiratory motion, with latency and acceleration. More precisely, the radiation therapy system presented in this paper is modeled as one-dimensional model with latency and acceleration with continuous and discrete (hybrid) dynamics using Open Modelica[3,4]; the model is investigated and analyzed with several artificial tumor movement trajectories. Simulations results indicate the model which outperforms the previous model by means of facilitating the specification and analysis of the radiation therapy system with respiratory compensation in an efficient and effective way.

2. RADIATION THERAPY SYSTEM

In this paper we analyze a particular setup, based on the Rubedo Systems iGuide, (http://rubedo.lt/Solutions/iGUIDE.aspx), consisting of the several components. **Patient Setup Couch** positions patient for the treatment, in our case it is HexaPOD couch[2]. The couch has 6 degrees of freedom: 3 x rotational movement and 3 x translational movement. **Tracking Device** provides the position of the marker or tumor. We model a system with a stereo camera, however in this model it is a device that just samples given trajectory with a preset frequency. **Controller** guides the treatment process. In our model it attempts to direct the HexaPOD in such a way that it follows the position provided by the camera as closely as possible.

3. MODEL AND SIMULATION OF THE RADIATION THERAPY SYSTEM

We use Open Modelica[3,4] to model the system. Separate components, i.e. controller, HexaPOD, stereo camera and controller are defined, and then merge them in one model. Current controller component is rather simple and is used as a placeholder to imitate latency[7]. Stereo camera component reads recorded trajectories from the file and provides them to the controller[7]. The most interesting part in this model is HexaPOD. We omit declarations due to space limitation and just present the algorithm.

```
model HexaPODSingleDim "Model of 1D HexaPOD with acceleration"
equation
der(x) = velocity;
if up then dir = x - target - velocity^2 / (2 * ACCELERATION); // movement up
     if dir <= 0 then if velocity <= VELOCITY_MAX then der(velocity) = ACCELERATION; //accelerating
                                                  else der(velocity) = ACCELERATION_ZERO; end if;
                else if velocity > 0 then der(velocity) = -ACCELERATION; // stopping
                                     else der(velocity) = ACCELERATION_ZERO; end if; // stopped
end if;
      else dir = target - x - velocity^2 / (2 * ACCELERATION); // movement down
     if dir <= 0 then if velocity >= -VELOCITY_MAX then der(velocity) = -ACCELERATION; //accelerating
                                                   else der(velocity) = ACCELERATION_ZERO; end if;
                else if velocity < 0 then der(velocity) = ACCELERATION; // stopping
                                     else der(velocity) = ACCELERATION_ZERO; end if; // stopped
     end if;
end if; // switching movement direction
when {(up and (x > target+delta)), ((not up) and (x < target-delta))} then up = x < target; end when;
end HexaPODSingleDim;
```

Simulation results are depicted in Fig. 1 and show, that HexaPOD succesfully follows required trajectory after initialization.

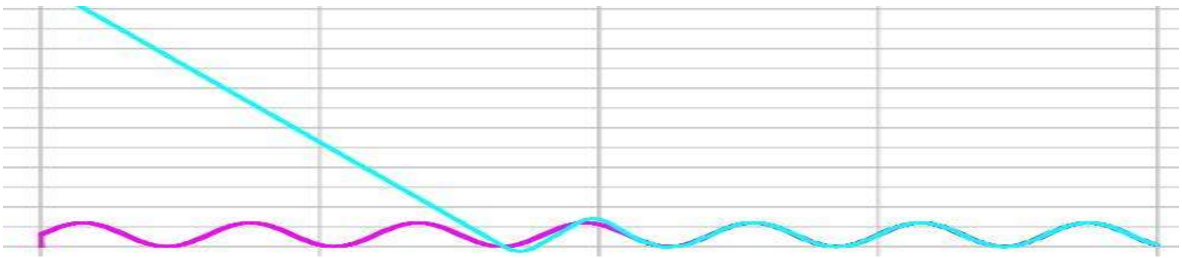

Fig. 1. Simulation Results: target movement and HexaPOD movement are depicted by violet and cyan lines, respectively. Vertical axis - position, horizontal - time.

4. CONCLUSIONS

Simulation results show that radiation therapy systems under development can follow movement of the tumor caused by the respiration after catching up with it. However, further investigation is necessary that follows trajectory with respiratory compensation and tries to predict the movement.

5. ACKNOWLEDGEMENTS

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