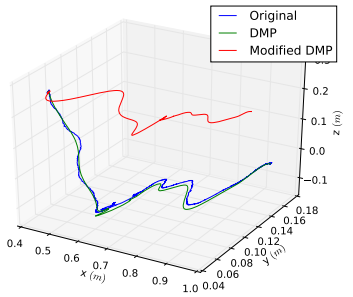

Figure 4: Left arm trajectory of Baxter

soft mannequin instead of a human for this experiment. Both the arms of mannequin are open and given support by a metallic stand, to avoid falling down the arms. Mannequin is positioned in such a way so that it resides within limits of workspace of Baxter robot. Both the arms of mannequin are facing towards robot. A Kinect V2 [1] sensor is mounted on LCD display of Baxter robot. Kinect sensor can see the mannequin and clothing article and provides depth information, which is necessary for mannequin tracking. The clothing article is put in the arms of Baxter robot manually before starting experiment.

Baxter robot is connected to a computer directly using Ethernet cable. It is controlled using Robot Operating System (ROS) [15], one of the widely used tools by the researchers in robotics community. We used Baxter robot's API, which is available and supported by ROS to command the robot. Kinect sensor is controlled by open source Kinect API for ROS [20, 21]. We performed following two experiments to validate our approach: (a) Clothing task using position DMP (b) Failure detection using end-effector forces.

4.1 Clothing task using position DMP

The aim of this experiment is to put sleeveless T-shirt on both the arms of mannequin by using DMP system. We use position data to initialize DMP trajectories, which are being used in this task. The posture of mannequin is changed. At this point, we use Kinect Sensor to get 3D coordinates of wrist and shoulder of mannequin. Now we change start and goal parameter of DMP trajectories by using this information. Modified DMP can be acquired by rolling out DMP system as described in section 3.1.

In this experiment, the initialized DMP was modified to accommodate new posture by changing start and goal parameter of DMP. The generated trajectory was then run on Baxter robot as shown in figure 4. Newly generated DMP trajectory (shown in red color) was not only found well suited and capable of performing clothing task but also smooth compared to original trajectory (shown in blue color). A video demonstration of this experiment can be seen at YouTube[1].

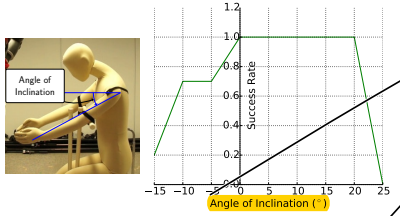

Figure 5: Accuracy measurement

To evaluate this experiment, we performed it many times and monitored trajectory generated by DMP system. We defined angle of inclination as the angle between arm of mannequin and horizontal axis. The angle of inclination is defined in clockwise direction, hence it is $+ve$ when arms are inclined upward, similarly it is $-ve$ when arms are inclined downward. It was changed by keeping arms at different-different height. The accuracy measurement is shown in figure 5. It was observed that DMP system was able to generate the appropriate trajectory for a range of 20° and it never failed in this range. However, as we keep on going far away from the original posture, success rate starts declining and finally reached to 0.

4.2 Failure detection using end-effector forces

This experiment is designed to deal with failure cases. There can be many failure cases during the task, such as clothing article gets stuck into the fingers, sleeve getting stuck on the arms, sleeve not entering the arm but entirely missing etc, as shown in figure 7. In this experiment, we are using forces being applied on the end-effector of Baxter robot to detect failure scenario. Appropriate action can be taken once the failure is detected.

The clothing task has to deal with complex dynamics including manipulation of clothing article. Clothes are non-rigid, flexible and highly deformable objects, making the task more difficult to perform. During the task, we observed forces being applied at both the end-effector of Baxter robot. Trajectories were monitored and categorized into two *success* and *failure*. The mean of these two categories is calculated and plotted as shown in figure 6. Force value is the norm of force applied in all three cartesian directions. This is the average profile over several *success* and *failure* trajectories for different postures of left arm of mannequin.

It is clearly visible from the figure 6 that the applied forces are very different in nature in both the cases. Both of these forces are increasing from the beginning, however, forces in case of *failure* are much higher than that of *success*. Hence one can easily differentiate and detect the failure by using this information.

[1] http://youtu.be/Rb2JePazJjk

注釈の一覧 :Robotic cloth manipulation for clothing assistance task using Dynamic Movement Primitives

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作成者 : Tom Shibata **タイトル** : **ハイライト表示** **日付** : 2017/02/10 16:16:38
Average angle of inclination?
How many samples for each angle?

作成者 : Tom Shibata **タイトル** : **ハイライト表示** **日付** : 2017/02/10 16:14:47
How many times?
What's their differences?
You need to write the experimental condition clearly and quantitatively as much as possible.

作成者 : Tom Shibata **タイトル** : **ハイライト表示** **日付** : 2017/02/10 16:15:28
v times e?
or 've'?

作成者 : Tom Shibata **タイトル** : **ハイライト表示** **日付** : 2017/02/10 16:17:47
Please add pictures showing the setup in the case of +ve and of -ve.