# Prototyping – Session Four Outline

## Purpose:

Assess three potential mechanisms that could be used to generate a hard surfaced used to improve uni-compartmental knee replacement surgical operations for user feel and range of motion.

## Background:

Previous prototyping sessions generated three mechanism that could facilitate 3D hard surface implementation. These mechanisms all utilize four linkages that allow for three degrees of freedom away from the hard surface and two degrees of freedom where the constraint is active. They are:

1. PT1b
2. PT3 (sizing: linear range = 12 – 16.5cm, offset = 9cm, link 4 = 10cm)
3. PT3b – evaluated using K’nex model only

Previous physical prototypes did not incorporate a tool mechanism into the user feel assessment. This negatively impacted the user feel assessment and resulted in poor overall performance of the design. Slight changes have been made to improve the each mechanisms characteristics and by incorporating a tool with freedom to rotate about link 4 and freedom to rotate on its own axis the user feel will be greatly improved.

# Previous Winnowing of Free Motion Concepts

Five ideas have been created to facilitate free motion of the tool in 3D space. A physical assessment of PT1 lead to the development of PT1b to improve user feel. An estimated envelope size has been generated and plotted using MATLAB

Table : Review of Prototype designs and evaluation prior to physical prototyping session 4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Description** | **Evaluation** | **Status** | **Feasibility** |
| PT1 | 1: rotational, joint 2: rotational, joint 3: fixed, joint 4: rotational | Poor user feel – tool position is limited to specific paths, limited envelope | PA[[1]](#endnote-1), EP[[2]](#endnote-2) | NO –  PT1b has been design to improve user feel by increasing the angle between the linkages during operation. For PT1b the average angle between link 1 and 2 is 90 degree |
| PT1b | joint 1: rotational, joint 2: rotational, joint 3: fixed, joint 4: rotational, tool is positioned in the same plane as joint 2 | Limited envelop, likely to have poor user feel due to fixed joint 3 | EP, no PA | Requires PA Review |
| PT2 | joint 1: rotational, joint 2: rotational, joint 3: rotational, joint 4: rotational | Good user feel, will require multiple hard constraints | PA, EP | NO –  Multiple hard constraints increase controller complexity and speed requirements |
| PT3 | joint 1: rotation, joint 2: linear, joint 3: fixed, joint 4: rotational | Envelop plot shows improved vertical travel, but is still limited | EP, no PA | Requires PA review |
| PT3b | joint 1: fixed, joint 2: linear, joint 3: rotational, joint 4: rotational | Envelop plot shows a significant improvement in vertical travel | EP, no PA | NO – will not be considered because design does not rotate about joint 1. This effects the path the tool takes across the knee and reduces the possible range of motion and user feel. |

1. PA stands for Physical Assessment, a review of the mechanism feel and envelop through user testing of a model [↑](#endnote-ref-1)
2. EP stands for Envelop Plot, an estimate of the useable workspace of the mechanism created by moving the each linkages through a range of a angles and plotting the cutting tool position

   # Prototyping Session Four Procedure

   The main purpose of this prototyping session is to assess the user feel and range of motion – operating envelop – of the mechanisms described above using a physical models. The models consist of each of the four linkages described above and a tool, held by the user, that can rotate about link 4 and revolve around itself.

   ## Operating Envelop

   The operating envelop will be assessed by tracing along a cupped hand centred at joint 1. The surgeon is assumed to mill along two different paths, NEED TO ADD PICTURE OFF TWO ORIENTATIONS; one in which the cutting motion is parallel to the joint 1 and one in which the cutting motion is perpendicular to joint one – i.e. parallel to joint 4.

   A successful design will be able to trace an 8cm by 8cm surface created by the cupped hand. The hand can be raised or lowered to assess the impact of vertical position on the operating envelope.

   ## User Feel

   The user feel will be assessed while tracing the surface of a cupped hand in both orientations described above, and will include; (1) tendency to force the user’s hand to twist during motion, (2) stability, (3) fluidity of motion, (4) interference with knee, and (5) user view of surgical area.

   Twisting at the tool position made the first prototype design almost unusable, but this is likely to be fixed by incorporating a tool with two degrees of freedom into the design. Stability will evaluate the tendency for the model to stay in position – upright. Fluidity of motion will evaluate how smooth motion is along the surface. Interference with knee will ensure that the mechanism does not inadvertently interfere with the knee within the full range of motion. User view of surgical area ensures that the user has full view of operating area while standing in front of the patient.

   # Model Pictures

   Include pictures taken during modeling and add lines that highlight tool motion and surface envelop to the surface of the hand.

   # Results

   |  |  |  |  |  |  |  |  |  |
   | --- | --- | --- | --- | --- | --- | --- | --- | --- |
   | **Model** | **Link Lengths [cm]** | **Operating Envelop** | **Preferred milling path** | **Twisting** | **Stability** | **Fluidity** | **Interference** | **View of surgical area** |
   | **K’nex PT3** | linear range = 12–16.5, offset = 9, link 4 = 10 | Sufficient | Could not assess due to flexibility of plastic linkages | Could not assess | Model tended to fall, top heavy | Could not assess | No interference noted | Concerns operating device using hand on the same side as mounting positiong |
   | **K’Nex PT3b** | linear range = 12–16.5cm, offset = 9cm, link 4 = 10cm | Sufficient | Could not assess due to flexibility of plastic linkages | Could not assess | Improved stability | Could not assess | No interference noted | Concerns operating device using hand on the same side as mounting positiong |
   | **Meccano PT1b** | Link 1=7.5, Link 2=7.5, Link 3=6, Link 4=120 including tool | Sufficient | Both orientations provide smooth motion, but rotation parallel to joint 1 minimizes total movement of linkages required | Tool could be held steady. Tool mounting design provides necessary freedom | Model showed some tendency to collapse, but could be supported my user in certain orientations. Gravity compensation is required | Fluidity of motion seems to be slightly obstructed by the top heavy design – additional linkageused to raise operating surface. Design determined to be sufficient | No interference noted | Concerns operating device using hand on the same side as mounting position |
   | **Meccano PT3** | Link 1=5.5, Link 2=7.5, Link 3=5, Link 4=6.5, Link 5=9.5 | Sufficient | Both orientations provide smooth motion, but rotation parallel to joint 1 minimizes total movement of linkages required | Tool could be held steady. Tool mounting design provides necessary freedom | Model showed less tendency to collapse. Gravity compensation is require | Smooth access to all portion of envelop. | No interference noted | Concerns operating device using hand on the same side as mounting position |

   # Conclusion

   Meccano PT3 though to be the best, because it provides all necessary range of motion and smooth operation but gravity compensation is likely to be easier.

   Add table compiling motor positioning assessment – general summary table.

   goal: select a linkage  
   - make sure has required envelope  
   - make sure can sure can be actuated  
   - make sure everything can be attached (actuators, ...  
   - make sure facilitates user/tool entry (lateral and frontal entry)  
   - make sure that user feel is adequate  
   - make sure that can make necessary cuts (what are we cutting out?)  
   - make sure gravity compensation will be OK? [↑](#endnote-ref-2)