Portable Self-propelled Force Feedback Device

Ayaka Fukasawa, Riho Taniguchi, Takumi Sato, Shoichi Hasegawa
Tokyo Institute of Technology

1. Background

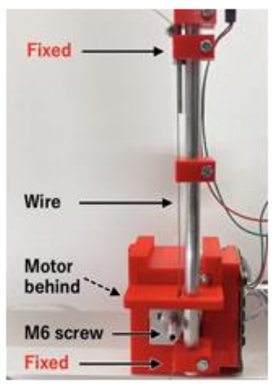
- Force feedback devices for VR prevent user's body from penetrating virtual objects and significantly facilitate manipulations and reality
- Conventional force feedback devices for external feedback forces are fixed to the ground, resulting in a limited workspace.(PHANToM [T. H. Massie et.al])
- An expanded workspace could be achieved by a device that is either large and heavy [J. Perret et.al 2009] or wearable [I. Choi et.al]
- A large external force can be applied to an admittance control device such as VISHARD6D [M. Ueberle et.al], but it is heavy, large, and dangerous

2. Purpose

- External force is presented by an impedance-type self-propelled device with no workspace limitation

3. Proposal

- overcomes the workspace limit by utilizing a driving unit
- Presenting 3-DoF with a back-drivable motor
- The horizontal force is presented at the driving unit
  - Two wheels are driven independently
  - front/rear forces are translational forces driven in the same direction
  - The left/right direction is the torque generated when the wheel is driven in the opposite direction.
- apply torque instead of a vertical force to the hand
- converted into vertical motion by a reduction mechanism
- Lightweight with impedance control



4. Device Control

- Force applied to hand : F_x, F_y, F_z
- horizontal presentation force

$$F_x = \frac{(f_1 - f_2)l_3}{2(l_1 \cos\theta + l_2)}$$

$$F_z = f_1 + f_2$$

- vertical presentation force
  - F_y and $F_y{}'$ is provided to the grip by torque T
  - F_y: The point that the vertical force is felt
  - Ignore $F_y{}'$ that generated naturally when the tilt of the grip is horizontal

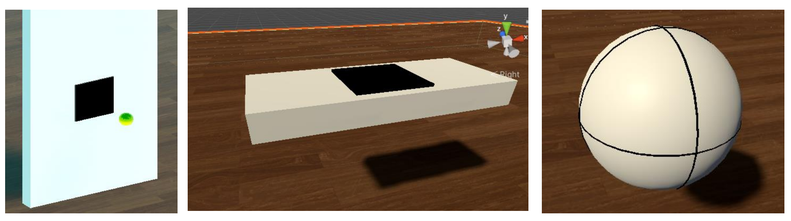
$$F_y = f_y + F_y{}'$$

$$-F_y l_h - F_y{}'(l_h + l_2) = 0$$

$$\therefore F_y = \frac{l_h + l_2}{l_h} f_y + \frac{T}{l_h}$$

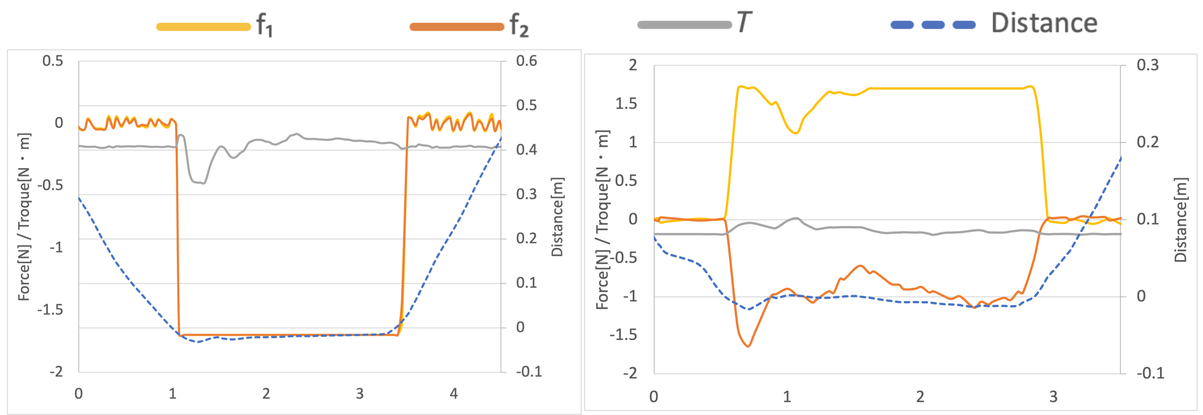
5. Experiment

- Prepare walls at different angles, a table and a sphere(diameter:0.5m)
- Measure the hand trajectory and the force of collision and object shapes when tracing black square/line

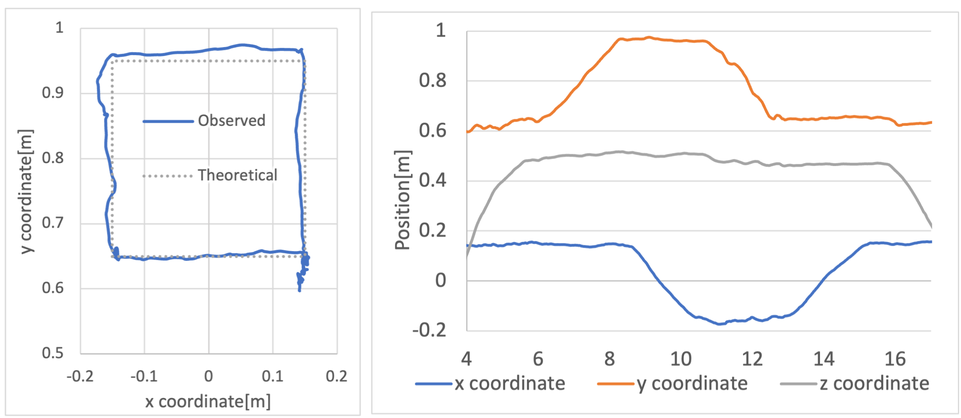


6. Result

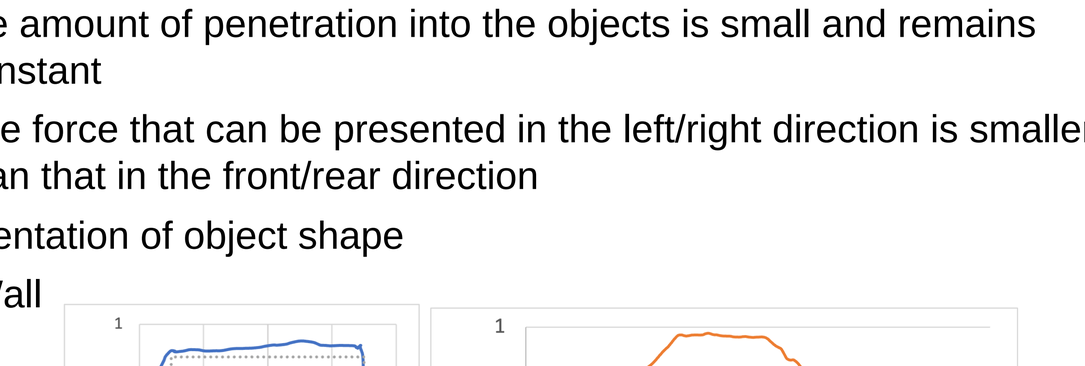
- The reaction force of the collision



  - the amount of penetration into the objects is small and remains constant
  - The force that can be presented in the left/right direction is smaller than that in the front/rear direction
- Presentation of object shape
  - Wall



    - the amount of penetration into the objects is small
  - Sphere



    - the amount of penetration increased when the surface normal is in the positive orientation of the y- and z-axis
      - a downward force is exerted on the grip by providing the presenting F_z
    - Penetration increases when the device's range of motion exceeds its limits

6. Conclusion

- force feedback reduced the amount of penetration
- for oblique surfaces, penetration increased depending on the normal direction

Portable Self-propelled Force Feedback Device

Ayaka Fukasawa, Riho Taniguchi, Takumi Sato, Shoichi Hasegawa
Tokyo Institute of Technology

東工大長谷川研 Haselab

1. Background

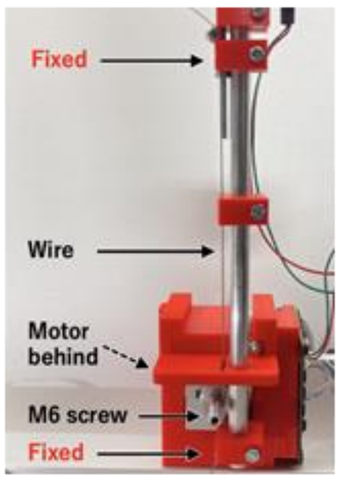
- VR上でフォースフィードバック装置は、仮想物体への貫通を防ぎ、操作性や現実感を著しく向上させる
- 従来のデバイスは、外部からのフィードバック力を得るために地面に固定されているため、ワークスペースが限られる(PHANToM [T. H. Massie et.al])
- ワークスペースの拡大は大型で重量のあるデバイス[J. Perret et.al 2009]か装着型デバイス[I. Choi et.al]が必要だった
- アドミタンス制御のデバイスだとVISHARD6D[M. Ueberle et.al]のように大きな外力を与えられるが、重くて大きく、危険が伴う

2. Purpose

- インピーダンス型の自走式で可動域制限がないデバイスによって外力提示する

2. Proposal

- 走行部を利用することで作業スペースの制限を克服
- バックドライバブルなモーターで３自由度を提示
- 水平成分は走行部で提示
  - 2 つの車輪は独立して駆動
    - 前後方向の力は同じ方向に駆動される並進力
    - 左右方向はホイールが逆方向に駆動する際に発生するトルク
- 垂直成分はトルクで代用
  - ネジとワイヤーによる減速運動変換機構を利用
- インピーダンス制御で軽量



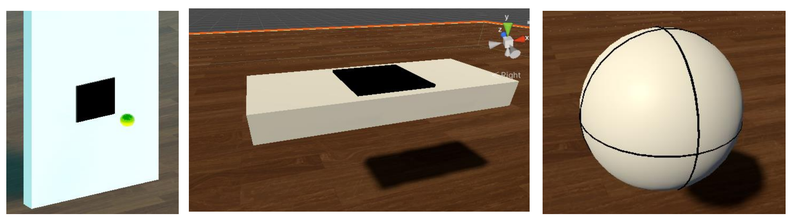
4. Device Control

- 手にかかる力：F_x, F_y, F_z
- 水平方向の提示力
  - $F_x = \frac{(f_1 - f_2) l_3}{2(l_1 \cos\theta + l_2)}$
  - $F_z = f_1 + f_2$
- 垂直方向の提示力
  - 上下方向はトルクTによって持ち手にはF_yと$F_y{}'$を提示
  - 上下の力を感じる点をF_yとする
  - 手を水平にする際に自然に出る力$F_y{}'$は無視する

$$F_y = f_y + F_y{}'$$
$$-F_y l_h - F_y{}'(l_h + l_2) = 0$$
$$\therefore F_y = \frac{l_h + l_2}{l_h} f_y + \frac{T}{l_h}$$

4. Experiment

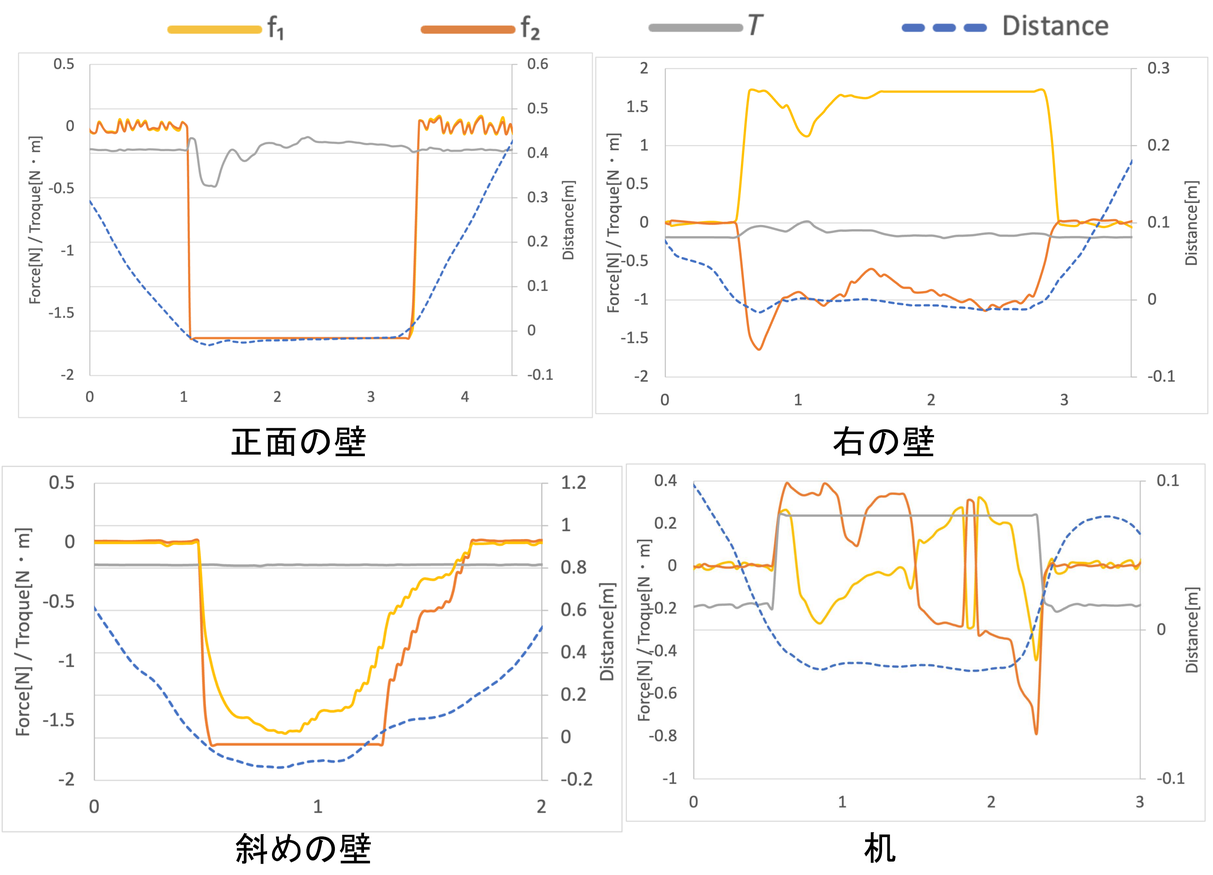
- 仮想環境上に角度の異なる壁(正面、右、斜め45度)、テーブル、直径0.5mの球体を用意
- 仮想物体への衝突感提示と物体形状の提示について調べた



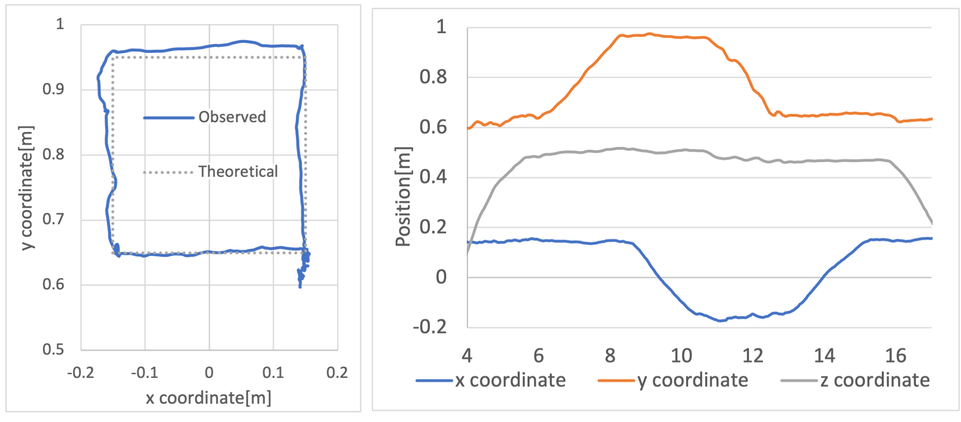
  - 衝突または黒い四角か黒い線をなぞったときの手の軌跡とデバイスが与える力を測定

6. Result

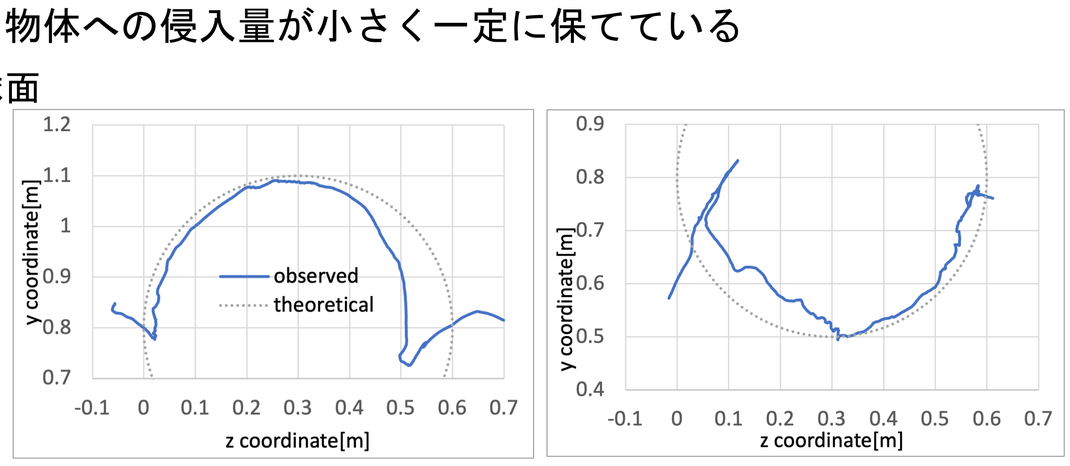
- 衝突の反力



  - 衝突方向の座標に変化がなく、衝突の反力が提示された
  - 左右方向は前後方向より提示できる力が小さい
- 物体の形状の提示
  - 壁



    - 物体への侵入量が小さく一定に保てている
  - 球面



    - 面の法線が y軸と z 軸が正方向の向きで球の侵入量が増加
      - 車輪で提示したz軸成分の力が持ち手から下向きの力として感じる
      - 上下方向を提示するトルクよりも感じやすく下に引っ張られる
    - 持ち手の可動域制限を超えると侵入量が増える

6. Conclusion

- このフォースフィードバック装置によって貫通量が減少した
- 斜めの面では、法線方向によって侵入量が増加