BME Design

MRI - Compatible Motion Platform

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Client: Mr. Jiayi Tang - UW Health

Advisor: Dr. James Trevathan

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Overview of Presentation

- Problem Statement
- Background
- Competing Designs
- Project Design Specifications
- Design Alternatives
- Design Matrix
- Future Work

Problem Statement

- Quantitative MRI (qMRI) measures physiological characteristics of tissues
- Calibration and quality of qMRI techniques are tested with controlled phantoms [1]
- Static phantoms do not represent physiological motion that alter imaging
- Design a MR-compatible device that will hold a phantom and simulate physiological movements
    - Respiratory motion
    - Liver phantoms
- Can lead to earlier detection of steatosis (affects 25% of population)

Background

- Client - Mr. Tang
  - PhD student in medical physics at UW-Madison
  - Research assistant in Quantitative Imaging Methods Lab
  - Studies improvement of motion robust fat and iron quantification MRI sequences
- Displacing ultrasonic motor from platform
  - Max Torque 1.2 N-m (supports weight of 9kg) [2]
  - $T=rF\sin(\theta)$
  - Axial radius 1.4 cm

Figure 1. Nonmagnetic ultrasonic piezoelectric motor [2]

Jamie

Competing Designs

Design 1

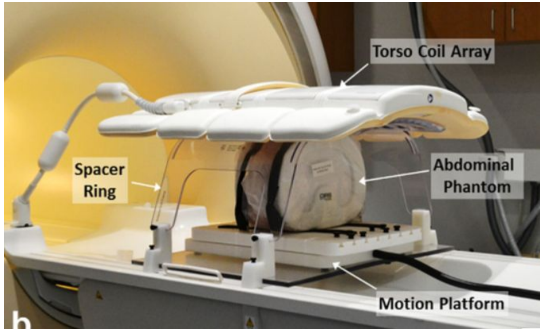

Figure 2. University of Texas Linear Motion Phantom [3]

Design 2

Figure 3. Vital Biomedical Technologies MRI Compatible Motion Stage [4]

Design 3

Figure 4. Quasar MRI Motion Phantom [5]

Project Design Specifications

- MR Compatible
- Create a prototype with a budget of $1000
- Utilize commercially available parts/easy fabrication
- Must support 4 kg and be larger than 25cm x 35cm [6]
- Supports physiologically realistic breathing frequency (eg. 8 cycles/min) [7]
- Supports a realistic amplitude (eg. 3cm) [3]
- Consistent for 10-15 minutes to 5% deviation [7]

Design 1: Lead Screw [8]

- Helix angle of thread driven by motor
- Variable efficiency
  - Higher helix angle → Higher efficiency
- Typically used for light loads less than 45 kg
- Friction wear is non-linear

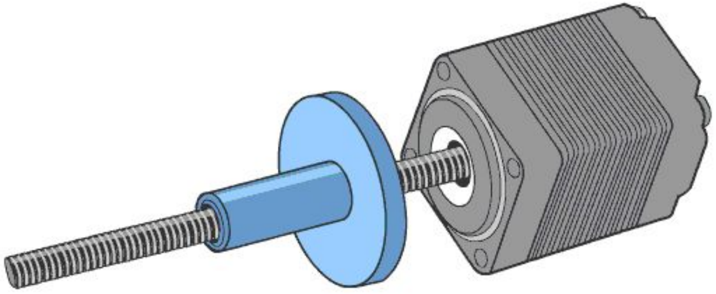

Figure 5. Animated Lead Screw [9]

Design 1: Lead Screw [8]

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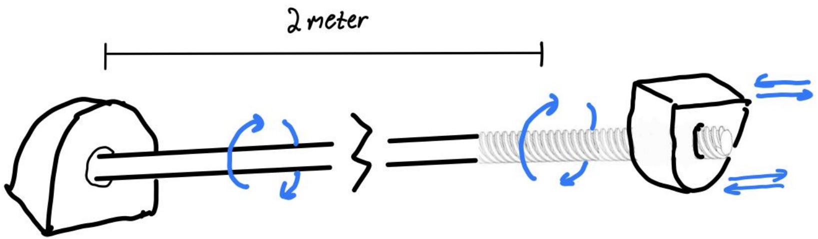

Figure 6. Lead Screw Design

Design 2: Scotch Yoke [10]

- Slotted yoke and a pin-mounted disc
    - Constant rotational speed creates sine wave motion
- Variable torque
    - Yoke closer to center → Higher torque
- Slot wears out quickly due to high contact pressures and moving friction

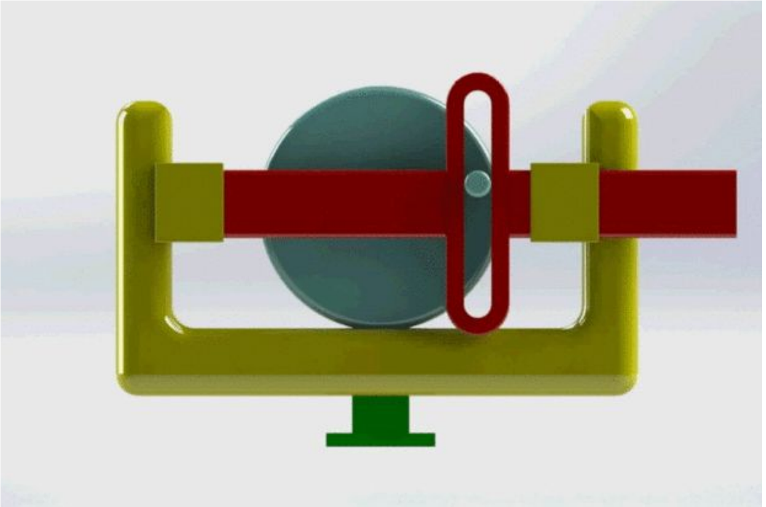

Figure 7. Animated Scotch Yoke [11]

Design 2: Scotch Yoke [10]

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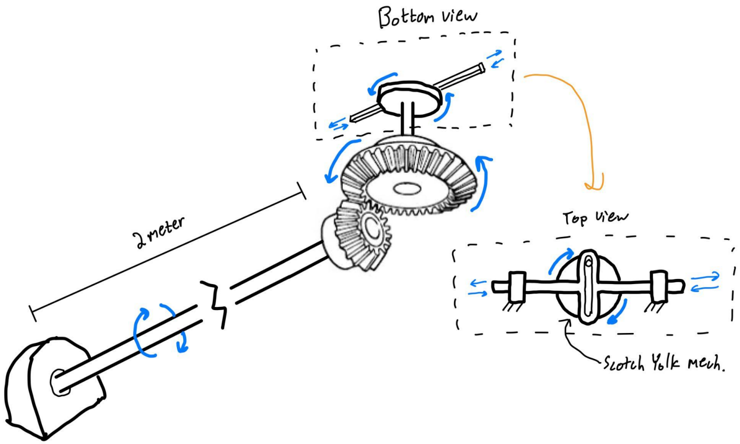

Figure 8. Scotch Yoke Design

Design 3: Rack and Pinion [12]

- Rotational motion (rack) transferred to linear motion (pinion)
  - High efficiency transfer
- Increasing gear teeth density
  - Increased precision
- Requires constant motor directional change
  - Causes stress on motor

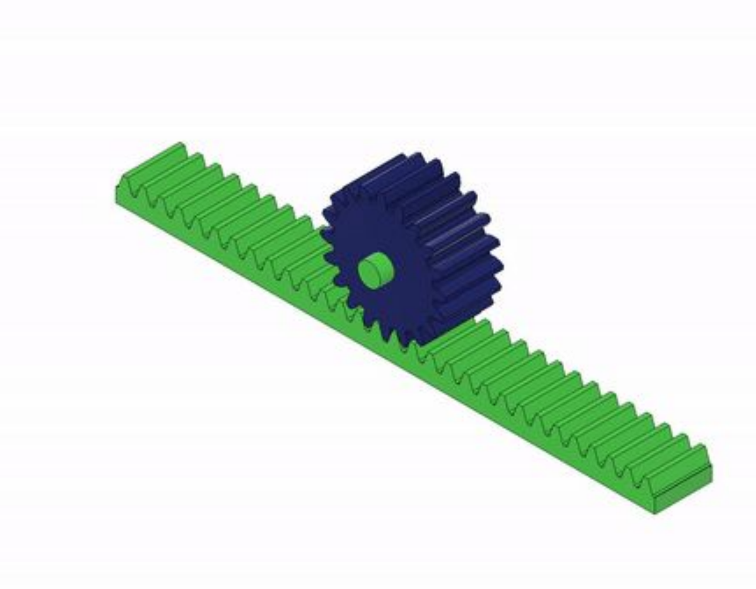

Figure 9. Rack and Pinion Animation [13]

Design 3: Rack and Pinion [12]

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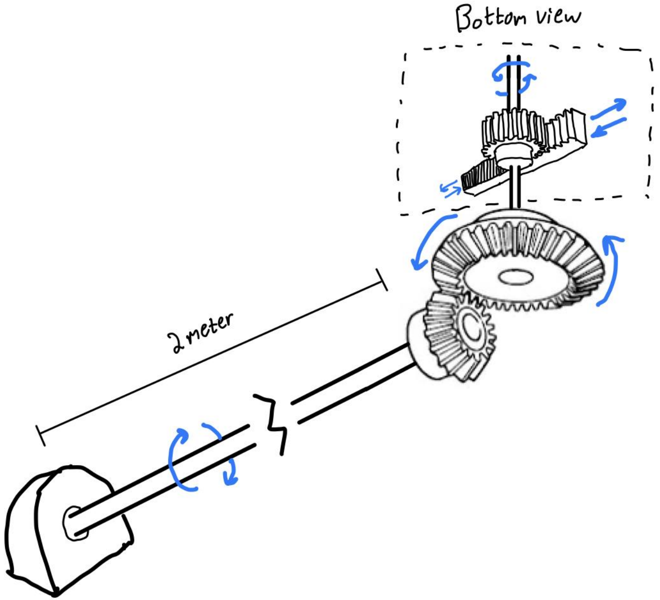


Figure 10. Rack and Pinion Design

Design Matrix: Prototypes

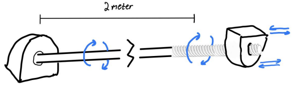
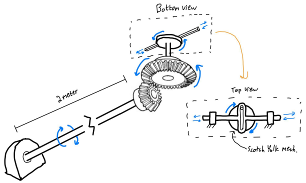
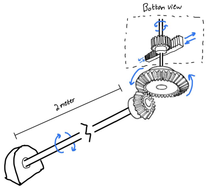
Categories	Lead Screw 		Scotch Yoke 		Rack & Pinion 	
Efficiency (25)	2/5	10	4/5	20	5/5	25
Accuracy (20)	5/5	20	3/5	12	4/5	16
Ease of Fabrication (15)	2/5	12	4/5	12	3/5	12
Cost (15)	4/5	12	3/5	9	2/5	6
Adjustability (10)	5/5	10	2/5	4	4/5	8
Safety (10)	4/5	8	2/5	4	4/5	8
Durability (5)	1/5	1	4/5	4	4/5	4
Total (100)		73		65		**79**

Table 1.
Design Matrix

Future Work

- October
  - Fabricate platform parts
  - Interconnect parts
  - Test Functionality
    - Gear Test
    - Speed Test
    - Load Test
- November
  - Determine Method of separating motor from the platform
    - Motor Test
    - Potential Meeting and Testing with Experimental MR

Figure 11. MRI Machine [14]

Future Work continued

- December
  - Software components and programming
  - Method of separating motor from the platform
  - Final Poster Presentation - December 8th
  - Final Deliverables - December 13th
- 2024 Spring Semester
  - Meeting with Client to Revise Proof of Concept
  - Work and Test integrative software
  - Test Updated Prototype

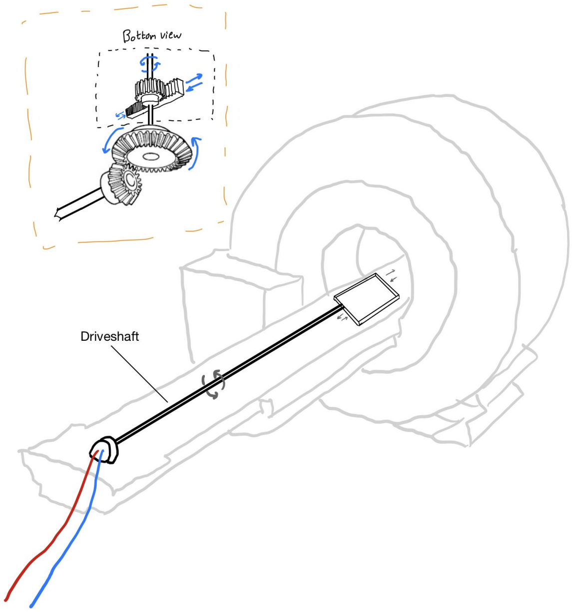


Figure 12. Final Design Setup

Acknowledgements

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Questions?

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