Magnetic Tweezers

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Background
- Magnetic tweezers were developed for microtological experiments and research purposes.
  - Measures the rheotogical properties of cells and tissues via the measurement of the trajectory of a tracer
  - Generates electromagnetic force to manipulate paramagnetic beads, creating a small force on biological samples, such as cells or tissues
- Related Technologies:
  - Optical Tweezers
  - Atomic Force Microscopy
- Benefits of magnetic tweezers:
  - Small-scale precision
  - Non-invasive, doesn’t damage specimens
  - Controlability through feedback loop

Purpose
Design and create a device to carry out active microtological force production in or on cells and tissues with control of bead movement in three dimensions.

Goals and Constraints
Goals:
1. Have 3D Control of Magnetic Beads
2. Measuring the Magnetic Force
3. Low Overall Cost

Constraints:
1. Budget
2. Microscope geometry
3. Electromagnet capability
4. COVID-19

System Functional Diagram

User Needs
- Feedback control
- Inexpensive
- Bead control
- Microlevel manipulation

Design Control Process

Design Input
- DC power supply (5-70amps)
- Heat treated Mu metal coils
- Olympus IX73
- Arduino circuit
- Tweezer angle (30°)
- Cost < $1,000

Design Process
- 3D modeling
- Electrical circuit design
- Academic research
- Current simulation
- Failure modes and effect analysis
- Calibration calculations

Design Output
- Labview integration
- Video tracking
- Medical applications
- Finite element analysis

System Functional Diagram

Magnetic Field Simulation
- Simulation done using Armys Maxwell 3D
  - 1 yolk modeled (3 electromagnets)
  - 500 coil wrap
  - 1 amp running through each
- Color gradient represents field strength
- Directional pull in center represents the direction of paramagnetic bead movement

Conclusions and Future Work
Conclusions:
- A hexapole system can be used to manipulate the magnetic forces in 3D
- This project can be achieved with a small budget
Future:
- Complete calibration of one tweezer with mechanical potentiometers
- Complete calibration of six tweezers with mechanical potentiometers
- Complete calibration with Digis
- Develop feedback control loop