WEEK 6

Article: Gervasoni *et.al.*, A Human-Scale Clinically Ready Electromagnetic Navigation System for Magnetically Responsive Biomaterials and Medical Devices, *Advanced Materials*, 2024.

QUESTIONS 6b

1. How does the Navion's triangular configuration of electromagnets improve its compatibility with fluoroscopic imaging? This configuration prioritizes fluoroscope C-arm mobility by sacrificing spherical field symmetry. Could this design limit access to complex 3D vascular structures? Figure 2 shows multiple different configurations in which the Navion system can be employed. In which situations/applications one configuration could be preferred over another one? What could be the factors (benefits/trade-offs) determining such choices? How could a double Navion like in Fig. S4 overcome these limitation while still being OR compatible?

2. Figure 5 presents different types of untethered device navigation systems. Could you explain the underlying principle that enables the controlled movement of such structures? Are the different kind of magnetic fields chosen because of the shape of the devices or of the different desired paths? Smaller object experiences drag force more significantly than the inertial force. Hence in the particle swarm model, the particles may become more difficult to locomote around the boundary of wall. Can we say that the rotating magnetic field is used to make particles to move constantly, making them to stick on the boundary less? In the experiments, pulsed magnetic gradients were used to steer a hard-magnetic sphere, while rotating fields controlled soft-magnetic and helical structures. Do the magnetic properties determine which actuation mode (gradient vs. rotation) is best suited?

3. In the in vivo porcine study, precise navigation of the magnetically-tipped catheter through complex arterial geometries, such as the tight curvature between the left common carotid and maxillary artery, was achieved via an external magnetic field system aligned to the pig's anatomy. Given the inherent spatial decay of magnetic field gradients with tissue depth and the non-uniform vascular branching angles, how did the spatial arrangement of the electromagnetic array and its field vector resolution constrain the catheter's ability to generate sufficient tip torque for reorientation at bifurcations? What modeling strategies or field-shaping techniques could be introduced to mitigate torque saturation or directional drift in future closed-loop systems?

4. The in vitro experiments demonstrate navigation of untethered microrobots in static fluid (Figures 5–6, Videos S1–S7). Given that blood flow in human vasculature is pulsatile with a cyclic pressure gradients (Flow with a Womersley number of 13.8 in the aorta), how would these microrobots behave under such dynamic conditions? Are there any control strategy to adopt e.g. pulsatile magnetic gradients? In the in vitro demonstrations as seen in Figure 5A, a 2 mm-diameter spherical magnet is navigated using pulsed gradients. How do the characteristics of the gradient pulses such as duration, amplitude, and direction influence the magnet's trajectory?

5. The article states that step-wise motion proved superior to continuous advancement for navigating magnetic catheters. Why? In Figure 9, we see that they use two magnets at the catheter tip. However, all magnets are controlled by the same field. Why would they need two magnets in a single tip instead of just one, as shown in the schematic of Figure 8?