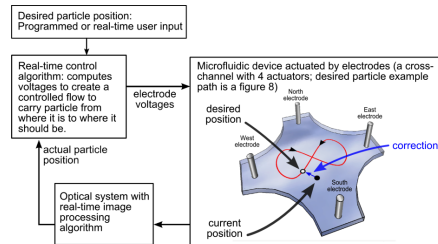


Control of Small Things

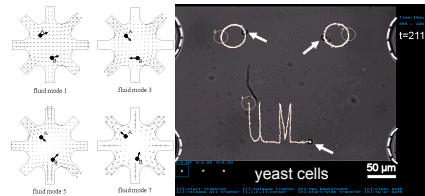
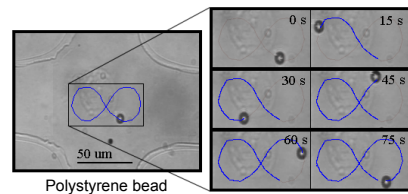
Benjamin Shapiro, M.Armani, M.Buck, Z.Cummins, K.Dormer, S.Kim, A.Komae, A.Lubbe, A.Nacev, R.Probst, C.Ropp, I.Rutel, E.Waks

Understand how to expand feedback control and systems thinking to micro- and nano-scale systems.
Whole path: from application ideas to systems modeling, control design, experimental verification, and commercial spin-offs.

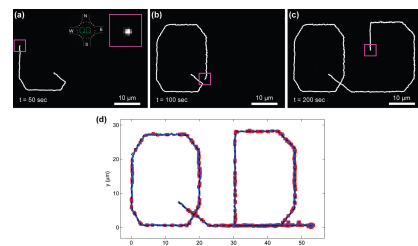
Control of Live Cells and Quantum Dots On-Chip



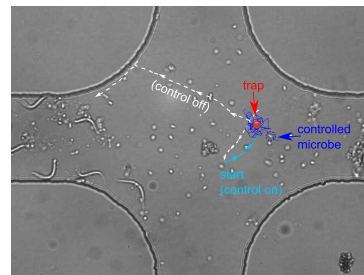
Simple, cheap PDMS devices trap and steer single and multiple objects to 1 μm accuracy



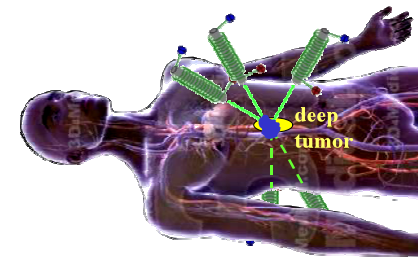
Unlike laser tweezers and DEP, forces on particles scale with radius (not volume) \rightarrow manipulate nanoscopic QDs to nm accuracy



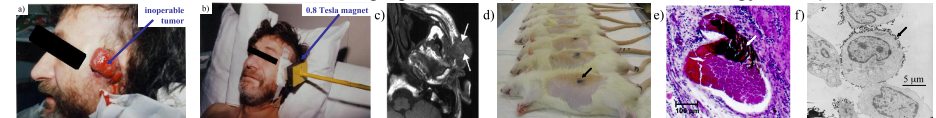
Can manipulate swimming micro-organisms and live human cells without harming them



Control of Therapeutic Nanoparticles in Patients



State-of-the-art: Human trials, MR imaging, animal experiments, tissue histology, cell uptake



Our current research:

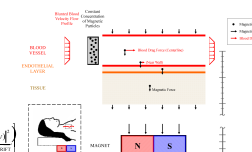
Modeling

Force on a single magnetic nanoparticle

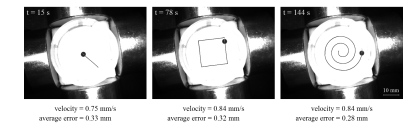
$$F_M = \frac{4\pi\mu_0\mu_r}{3} \left(\frac{d\mathbf{M}}{dt} \right) \cdot \nabla \left(\frac{1}{r} \right) = \frac{2\mu_0}{3} \frac{\mu_r}{(1+\chi/3)} \nabla \left(\frac{1}{r} \right)$$

PDE for transport of ferrofluid in blood/tissue

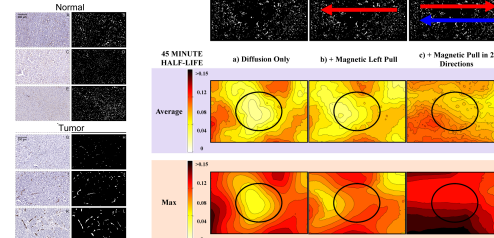
$$\frac{\partial}{\partial t} C(\mathbf{r},t) + \nabla \cdot (C \mathbf{v}) = D \nabla^2 C + C \nabla \cdot \mathbf{v} + \nabla \cdot (C \mathbf{v})$$



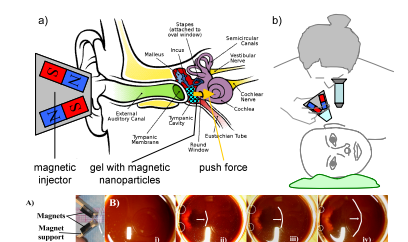
Control experiments



Based on autopsies ..



System to magnetically inject (commercializing ..)



Join control/systems thinking with medicine, biology, chemistry, electronics, & micro/nano-fabrication.
Systems to better diagnose diseases, focus chemotherapy, and create quantum information devices.