"Mathematics of novel materials from atomic to macroscopic scales"

Abstract: Materials' electronic properties arise from the complex dynamics of electrons flowing through the material. These dynamics are quantum mechanical and realize many surprising phenomena without classical analogues. I will present analytical and numerical work clarifying these dynamics in three novel materials which have attracted intense theoretical and experimental attention in recent years: graphene, the first `2D' material, whose electronic properties can be captured by an effective Dirac equation; topological insulators, whose edges host surprising one-way edge currents; and twisted bilayer graphene, an aperiodic material whose properties can be captured by an effective system of Dirac equations with periodic coefficients. I will then present ongoing and future work focused on further clarifying the remarkable properties of twisted bilayer graphene, which was recently shown to superconduct when twisted to the `magic' twist angle 1 degree.
Robots are usually programmed for repetitive tasks in a structured environment or particular tasks in a less structured environment with a considerable amount of hand-crafted tuning work. Recently, the attention of robotics is redirected from mass production to mass customization. Existing planning and control techniques have a very limited capacity to respond to such a trend: whenever a new type of tasks or a new robot with different dynamics is presented, the hand-crafted baseline planning and control algorithms for the robots usually have to be re-derived and the actions for robots to take have to be re-programmed. This talk will present my group’s recent studies on learning-based planning and control that aim to overcome such limitations and establish robotic systems that are capable to continuously learn from and collaborate with others. I will particularly discuss these studies within the applications to drones for their mass customization and applications, as well as collaborative robots for disassembly to improve efficiency and effectiveness of e-waste recycling and remanufacturing.

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