Tata Institute of Fundamental Research

Survey No. 36/P, Gopanpally Village, Serilingampally Mandal, Ranga Reddy Dist., Hyderabad – 500 046

Seminar

Non-equilibrium Systems under Geometric and Informational Constraints

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This thesis investigates how geometric and informational constraints govern the dynamics of two classes of athermal non-equilibrium systems: granular materials and autonomous robots.

Granular flow through confined outlets is disrupted by the spontaneous formation of mechanically stable particle arches, a phenomenon known as clogging. We show that a cylindrical obstacle of diameter roughly half the particle diameter optimally suppresses clogging in a 3D hopper, governed by a universal geometric criterion: maximum flow facilitation occurs when the clearance between the obstacle and the hopper wall equals a few particle diameters. The obstacle renders load-bearing arches asymmetric and mechanically fragile. Further, axial reciprocating motion of a wire or rod in a 3D hopper actively breaks clogs at power inputs of order milliwatts, enabling controlled flow modulation.

Efficient robot navigation and coordination are complicated by motor asymmetries, environmental noise, and communication latency. We show that first-passage times to a target depend non-monotonically on heading-correction frequency, establishing an optimal intermittent reset strategy that minimizes travel time without continuous feedback. For robot swarms, achieving global geometric order, such as line formation, intuitively demands extensive knowledge of the entire group's configuration. We show, however, that robust nematic ordering and spontaneous line formation emerge even when each agent samples as few as two peers, demonstrating that sparse non-local positional information is sufficient to drive global ordering.

Monday, Jun 15th 2026

11:30 Hrs (Tea / Coffee 11:15 Hrs)

Auditorium, TIFRH