The goal of the project is to study interactions between particles and their segments in fluids so viscous that the effects of fluid inertia are negligible. Influence of the fluid boundaries and possible electric charges on the particle surfaces will be also taken into account. Hydrodynamic (e.e., mediated by the fluid) interactions between particles of different shapes and rigidity, between their segments and the nearby walls will be investigated. Systems of the particles moving under gravity and immersed in an external fluid flow will be considered. In particular, hydrodynamic interactions between elastic filaments and their parts will be studied, both for linear and closed chains. Characteristic patterns of their relative motion will be investigated and their stability or instability will be found. Generic instability or stability of different shapes and relative configurations will be also determined. Transport coefficients of suspensions and streaming currents close to particle-covered surfaces in the presence of charge will be evaluated.

The experience gained so far in experiments and numerical simulations allows to plan in the present application more advanced research tasks, and focus on many-body effects for particles of different shapes, including also interactions of particles with the boundaries: interfaces or walls. Moreover, our present experimental studies are focused on short-time effects. In this proposal, they will be extended by using the new device moving the cameras with the particles settling under gravity in a viscous fluid. The device will allow to study the long-time and long-distance effects, typical for hydrodynamic interactions. The new device to move cameras and control their positions will allow to test our numerical predictions of the particle dynamics and gain understanding of long-time effects, such as formation of groups, repulsion or attraction of particles and their orientational ordering and interactions with the walls. In the present proposal, we plan to use new theoretical tools to analyze dynamics of flexible fibers - simplified models of very thin filaments.

Experimental, numerical and theoretical methods will be applied to study the hydrodynamic interactions described above. In experiments, millimeter-sized particles settling under gravity in a very viscous silicon oil will be used, in the absence of fluid inertia. Two synchronized cameras will document the time-dependent particle positions at two orthogonal projections, to provide information about the three-dimensional particle shapes and motions. Owing to the similarity principle, the experimental findings of the project will provide information about dynamics of geometrically and hydrodynamically similar systems of microparticles (with the same value of the Reynolds number which is the product of a characteristic size and velocity, divided by the fluid kinematic viscosity).

In the numerical simulations particle shapes will be modeled as a collection of beads very close to each other. In deformable objects, beads will be connected by elastic forces. Precise multipole algorithms of solving the Stokes equations, corrected for lubrication and implemented in the Hydromultipole numerical codes of controlled accuracy, and also simpler hydrodynamic multipole approximations will be used to determine evolution of each bead. To determine transport coefficients of suspensions and streaming currents close to particle-covered surfaces, basic concepts of the virial and cluster expansions from the statistical mechanics will be applied together with some numerical simulations based on the Hydromultipole numerical codes. Instabilities of shapes of elongated deformable particles we will be analyzed using standard and generalized models of very thin elastic filaments.

Hydrodynamic interactions between microparticles of different shapes and elasticity moving in water-based media or undergoing forces exerted by the fluid have been recently studied in many internationally recognized laboratories. Our combined experimental, numerical and theoretical approach will significantly contribute towards this research. The motivation comes from rapid development of modern technologies and materials, such as, e.g., production of elastic hydrogel filaments. Knowledge of basic principles of the dynamics of elastic filaments in fluids (or more general, many-body hydrodynamic interactions) is important for development of applications.