DESCRIPTION FOR THE GENERAL PUBLIC

The aim of this project is a mathematical study of solutions to nonlinear systems of partial differential equations stemming from natural sciences: mathematical biology and continuum mechanics.

Partial differential equations are the essential mathematical tool of natural sciences. They lay at the heart of the modern physics and other natural sciences, since they describe a bulk of natural phenomena (e.g. diffusion, wave propagation, fluid motion, general relativity)

Within my project, I intend to study:

A. Solutions of partial differential equations systems associated with chemotaxis, more precisely, of the nonlocal Keller-Segel system.

Chemotaxis is defined as an ability to move in response to a chemical signal. The prominent examples are feeding and mating behaviors induced by pheromones (e.g among insects). From the perspective of biological and medical sciences, equally important is chemically-induced morphogenesis and healing. An example of the former may be angiogenesis in relation to tumor growths: tumor tissues send a chemical signal that forces organism to create blood vessel feeding the tumor. Naturally, it is crucial to understand and prevent this mechanism. An example of the latter may be the fact that neutrophiles neutralize bacteria via a chemical `homing' mechanism.

The main goal of my project in relation to the non-local Keller-Segel system is to prove that its so called `critical case' behaves differently than conjectured in the existing literature: namely, that its solutions remain smooth for all times. The reason for undertaking this research subject is on the one hand, my taste to deal with problems that posses a strong real-life justification and on the other hand, my desire to address analytical difficulties related to an open research question posed by experts in the field.

B. The existence, uniqueness and optimal regularity of solutions to systems of partial differential equations from continuum mechanics, more specifically, from the non-Newtonian hydrodynamics.

The theory of continuum mechanics is one of several primary major branches of mathematics from a perspective of its applications. The Navier-Stokes system models the flow of an incompressible viscous liquid. The unsolved question of uniqueness and regularity of its solutions has been posed as the 6. Millennium Problem. My interests concentrate around a non-Newtonian version of the Navier-Stokes system. It model a flow of non-Newtonian fluids, like blood, certain suspensions, asphalt, emulsions.

The main goal of my project in the field of continuum mechanics is to show existence, uniqueness and optimal regularity of a steady, non-Newtonian Stokes system with very irregular forces (i.e. to provide virtually complete analysis of the model). Here, as before, the reason for choosing the research subject is on the one hand my need to deal with equations modeling physical processes, and on the other my ambition to answer a major analytical open question: in this case, it is an open issue of developing a so-called `nonlinear Calderón-Zygmund theory' for right hand sides with their regularity substantially below the one given by a natural duality.