Master’s Thesis Topic:
Dispersion optimization of chiral metamaterials: an analytical design

Description:
Metamaterials are solids with carefully architected microstructure often times not found in nature. Among the myriads of designs, the combination of lattice architectures with mass and inertia elements has recently revealed the ability to realize promising dynamic properties, such as low frequency bandgaps in stiff, low-density structures, as well as the ability to tailor them [1]. In this Master’s thesis project the focus will be on analytical and computational design and optimization of chiral elastic unit cells. The basic idea is to treat the elastic element in panel (a) as a 'lego brick' from which to construct more complex structures, with periodicity in one-, two- or three-dimensions. With the help of basic solid mechanics, the bricks will be assembled together, giving rise to relatively compact dispersion equations and, in turns, the relation between wave-number and frequency. The full control over the geometric parameters granted by the analytical approach will allow the expedite optimization of the dispersion relations, such as the group and phase velocity for elastic waves. The analytical design of the unit cell will be compared to their finite-element dispersion diagrams and modal responses, as done for the harmonic response of the base cell in panels (b) and (c) (rotational and linear motion of the disk, respectively). The use of numerical topology optimization is foreseen at the latest stage in order to accommodate the requirements of the design and the constrain imposed by a table-top 3D printer. The successful completion of the project will have a relevant impact on the design of elastic structures with improved fluid-solid interaction.
Individual tasks:

- Familiarize with the kinematics and dynamics of the base element in panel (a), building upon existing literature [1].
- Familiarize with simple models of wave propagation in periodic chains and networks of masses connected by rods and/or beams [2].
- Construct and/or update matlab scripts for the assemblage of the stiffness matrix of unit cells comprising repetitions of the basis structural element in panel (a).
- Solve dispersion equations using linear algebra or root-finding packages in Matlab.
- Investigate the effect of design parameters on the dispersive properties of the unit cells.
- Compare the proposed design to full scale finite element models of dispersion (using in-house codes [3] or commercial packages).

References

