**Possible topics from PepsiCo for the SAMBa June ITT**

 **A summary by CJB of the meeting at PepsiCo on 14th February 2019**

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All of the topics discussed looked at the modeling of different processes in the manufacture and distribution of fabricated potato chips (crisps) and related products such as quavers, and the estimation of the various material and other properties of these products given information about their micro-structure. I think that these are all excellent problems for an ITT.

**1. Stochastic/statistical bubble expansion model**

Bubbles are important in food manufacture and affect such properties as the visco-elastic mechanical deformation and also the heat and mass transfer characteristics. The growth of bubbles is governed at a local level by a well-defined system of PDEs. However there is a lot of associated uncertainty about the distribution of the nucleation sites and the non-heterogeneity of the parameters.

**2. Statistical fracture mechanics modelling for texture detection**

Fracture mechanics plays a vital role in the manufacture of potato chips and quavers. It affects both the manufacture and transportation of the product, and also the eating and chewing experience of the consumer (is it crunchy or not?). Foods themselves are inhomogeneous and multi-scale in nature, often taking the form of a foam/solid combination. The question posed is whether we can construct a model (analytical or statistical) that allows PepsiCo to estimate the yield strength of a food product given information about the micro-scale and other properties such as the density of the foam, of the solid, the mass fraction of solid and the anisotropy ratio.

**3. Statistical realignment of chips on two supports**

This is a mechanical problem. The chip (approximately like a circular arc in cross section) is positioned so that it is supported at two points. At each point there are forces due to a reaction and friction. The question is then what is the most stable way to align the crisp. There is a significant statistical aspect to this problem due to the uncertainty in the chip shape, thickness, brittleness and also in the various friction parameters. It is a nice combination of statistics and classical mechanics. An important consideration is the volume of chips (10 per second over 20 lanes = 200 chips per second) that need to be aligned,

**4. Going from a micro-structure to material properties**

The question here is what aspects of the micro-structure of a chip contribute to its overall material properties. These might, for example, include its mechanical, rheological (such as the elastic modulus) and thermal properties (such as specific heat and thermal conductivity). Can we predict, for example, the probability distribution of the material properties?

This is a huge question, which could occupy many students for a long time. Two approaches are possible. One is a modeling approach in which a homogenization method is used to go from the small scale to the large scale. (CJB has used this approach to understand the properties of trees, starting from a cellular level). The second would be a machine learning/statistical approach in which we attempt to correlate the micro and macro structures.

**5. Seasoning chips with a powder**

The flavor of a crisp is applied to it via a seasoning powder. The powder has different particle sizes. The powder is shaken from an oscillating belt and then falls on to the chip. The belt The question is, what is the best way to shake the powder so that it is most uniformly spread over the chips as they move past the shaking device. There are currently problems with a lack of uniformity in the powder distribution on the chips

There is huge potential here for both a modeling, and a statistical approach, which makes this very suitable for an ITT project. We can consider the way that the powder leaves the shaker, the way that it falls through the air onto the chip, the statistical make up of the falling powder, and the way that it is distributed on the chip. For example, is it random, or do we see systematic patterns developing. (In electrostatic painting with a charged paint powder the latter is clearly seen). There is a degree of psychology in what would be perceived as a ‘well flavoured chip’. Analogies were made with the earlier ITT problem of seed spreading.

**6. Material Handling Problem**

Potato chips are similar in shape and size, but are not identical. When they are sliced they fall onto a flat conveyer. The question then arises as to what it the best way to pack them onto the conveyer so that there is minimal spacing between them. A related question (in three dimensions) is the best way to pack oddly shaped chips into a bag. Both of these are problems in stochastic optimsation given the uncertainty in the shape of the chips.

CJB 26/2/19