Observation Based Modeling of Liquid Slosh in Drop Tests

Victor Ekblad and Axl Roos

Centre for Mathematical Sciences | Faculty of Engineering | Lund University

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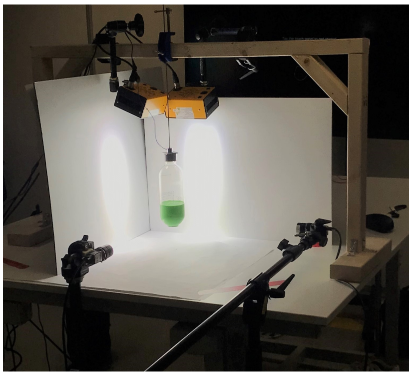
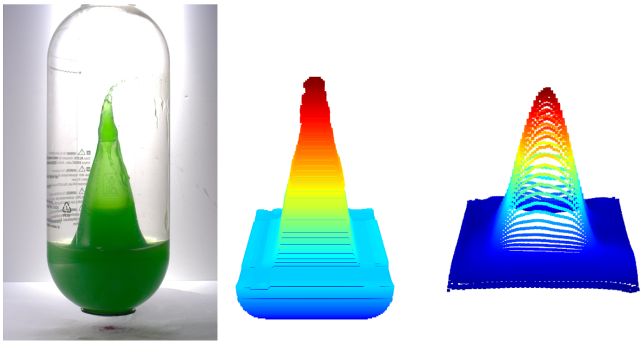
Fluid dynamics is a notoriously difficult and unintuitive branch of physics. Computer simulations are often utilized to solve these types of problems, but to trust these models we first have to observe what happens in the real world. This work aims to build a solid data gathering framework to capture how different liquids behave when dropped from different heights in a controlled setting. The data is then used to create completely data driven models with neural networks, which can run way faster than the physics based models.

Tetra Pak® is a well known food packaging company with many customers world wide. If you take a look inside your fridge you will probably spot a few Tetra Pak® packages of different kinds. Creating a new product takes time and during the development of new packages different tests are conducted. One way to inspect the durability of a package is to drop it and inspect the damage. However doing this in practice for new prototypes can be time-consuming and a waste of materials. Therefore virtual prototypes are created and used in simulations where it is easier to make small changes in a faster way. For these virtual models to give reasonable results the package and liquid interaction has to be modeled in the correct way. At the beginning of this work the liquid could not be properly modeled during a drop inside of a bottle. This work was therefore initiated to create a framework to gather data and thereby gain more knowledge from different drops and liquids, and also to process this data and feed them to machine learning models for prediction of the liquid behavior. These machine learning models can then be used to make approximate predictions in seconds, compared to hours or even days for physics-based models.

To capture data we built a rig and fixed a rod and an electromagnet to it. By gluing a steel plate to the top of our bottles we could, with the press of a button, deactivate the electromagnet and start filming the drop using two cameras.



Using image analysis and computer vision algorithms we could produce 3D reconstructions of the surface of the liquids during these drops. This data was then fed to a type of neural network called a U-Net, which after training could predict the motion of the liquid, being told only which height the bottle was dropped, the fill level, and type of liquid. In the figure a drop image, the 3D reconstruction, and the prediction from the U-Net is illustrated for never-seen-before data.



The collected data was also used to improve and verify new physics-based simulation at Tetra Pak®.