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"Smart-Spheres" for environmental monitoring and risk assessment applications

Introduction

Sediment transport, due to primarily the action of water, wind and ice, is one of the most significant geomorphic processes responsible for shaping Earth's surface. It involves entrainment of sediment grains in rivers and estuaries due to the violently fluctuating hydrodynamic forces near the bed.

Here an instrumented particle, namely a "**smart pebble**", is developed to investigate the exact flow conditions under which individual grains may be entrained from the surface of a gravel bed. The device is focusing on the use of low-cost 3D-printed shell, implementation of low-power off-the-shelf modular electronic components, and usage of appropriate sensors offering better resolution and accuracy.

This could lead in developing a better understanding of the processes involved, while focusing on the response of the particle during a variety of flow entrainment events.

Figure 1. **Challenges: a) flooding, b) sediment transport & erosion, c) scouring**

Objectives

- Develop a particle instrumented with MEMS sensors appropriate for capturing the hydrodynamic forces during a variety of flow entrainment events on the river bed.
- Create a program to collect the sensor's 3-axes measured acceleration and rotation data and store it in a memory.
- Calibrate and analyse the data when testing the particle in controlled and simulated flow conditions respectively.

Conceptual design

- A tri-axial accelerometer registers data to a memory card via a microcontroller, embedded in a 3D-printed waterproof hollow spherical particle.
- The instrumented board is appropriately fit and centered into the shell, in order to achieve a nearly uniform distribution of the mass.
- An independent power supply ensures autonomy and provides appropriate long periods of operation.
- Data post-processing and analysis are currently performed offline.

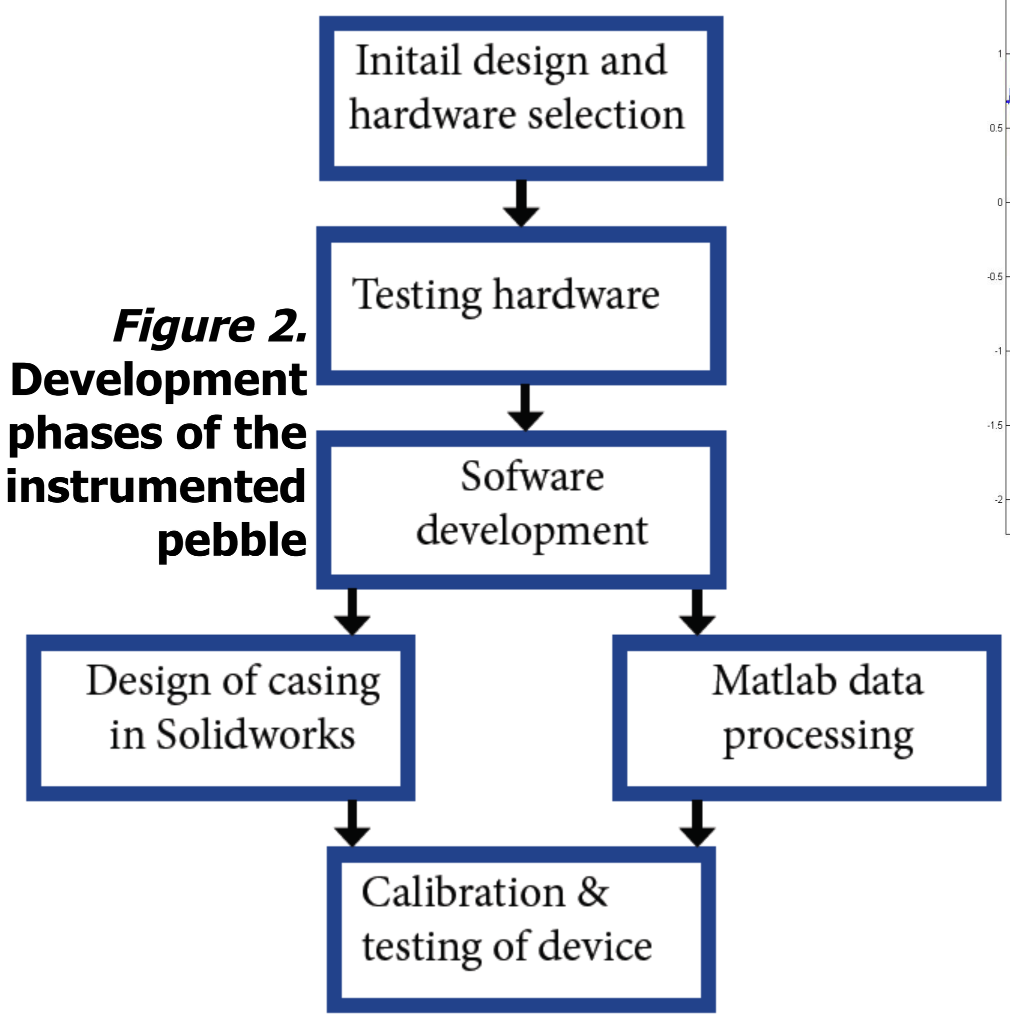

Figure 2. **Development phases of the instrumented pebble**

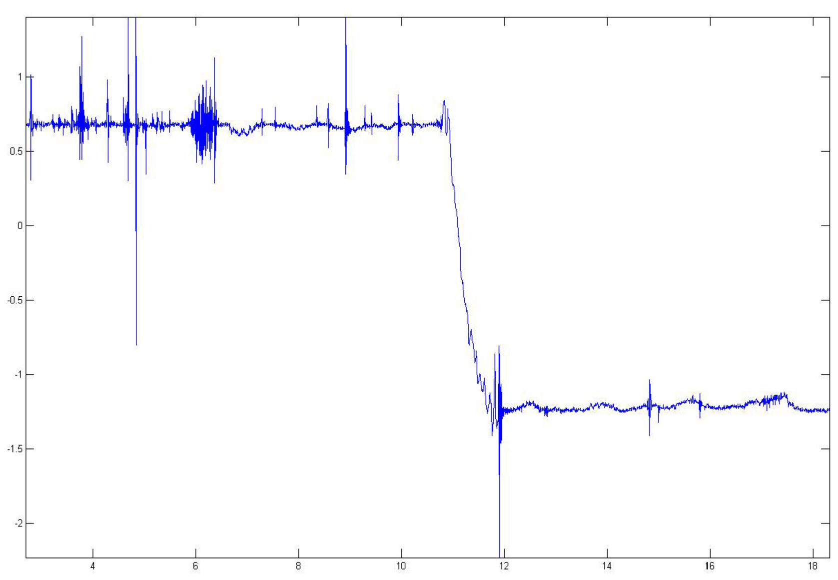

Figure 5. **Typical acceleration readings (z-axis component) of the "smart pebble"**

Development process

- A Digital Axis Accelerometer and Gyro Breakout MPU6050 are used, offering great range of measurements (±16g), noble sensitivity and simple calibration process.
- The FRDM-KL25Z is a microcontroller development board featuring the energy efficient Cortex M0+ processor.
- The shell was generated via Solidworks. The particle is divided in two halves, using plastic material of sufficient hardness. An inter-lock mechanism securely joins them together ensuring the particle is sealed and waterproof.

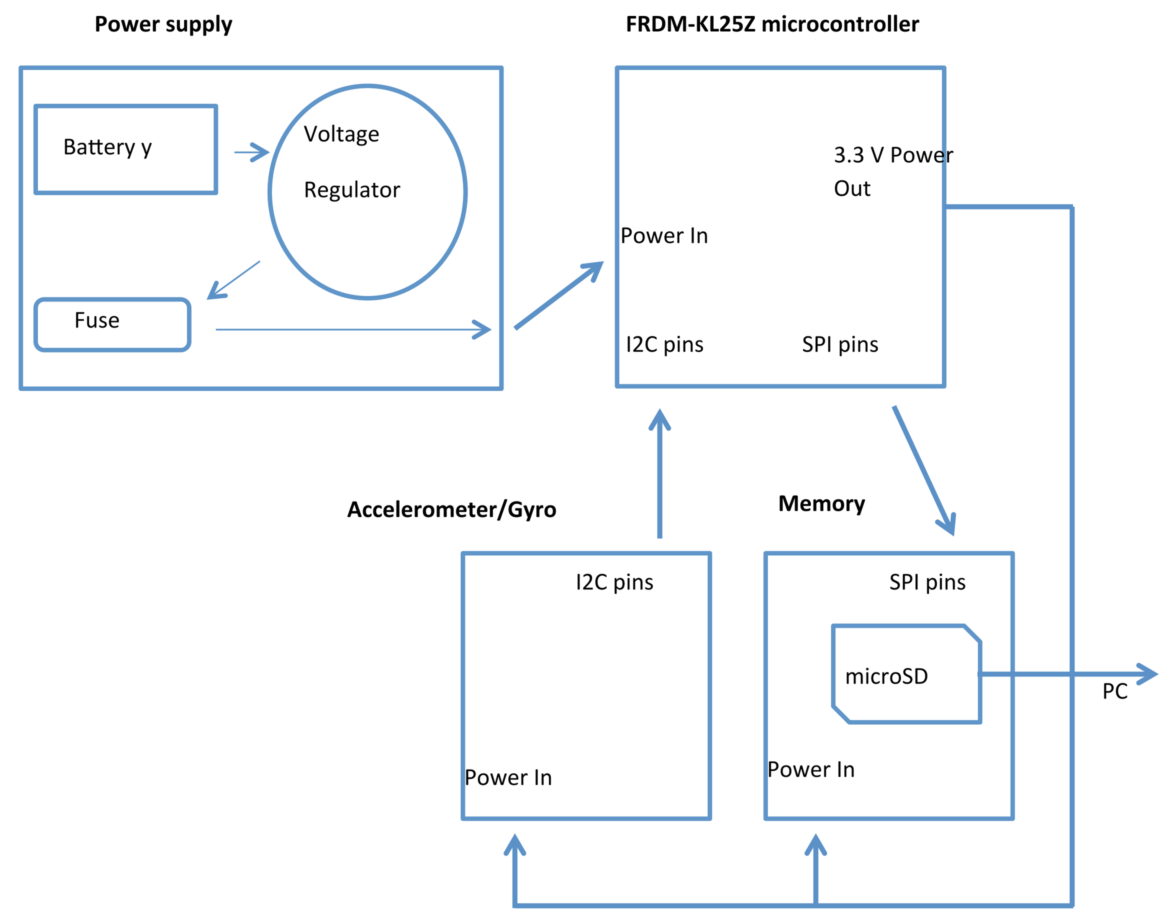

Figure 3. **Schematic of the designed electronics board**

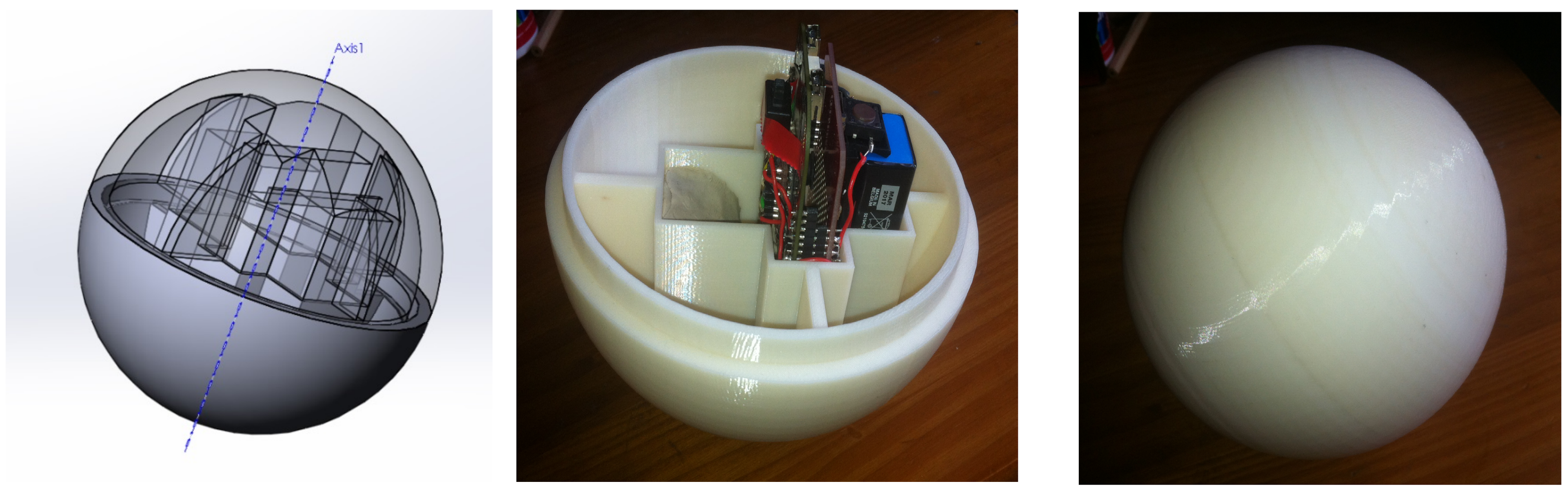

Figure 4. **3D design and development of the "smart pebble's" enclosure**

Calibration and data analysis

Calibration was achieved using a high speed camera to monitor its rotation and acceleration during: a) a linear descent along an inclined plane, b) 360º rotation about a fixed point, c) random motion on a vibrating table.

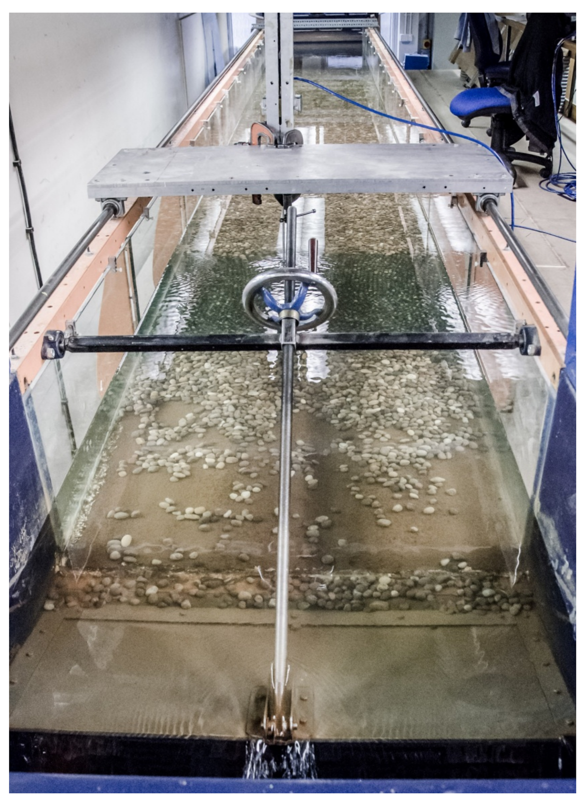

Figure 6. **Downstream view of the tilting flume where preliminary tests under controlled unsteady flow hydrographs were run**

Conclusions

The device has been tested over a wide range of accelerations and angular displacements, and can shed light into the dynamics of particle entrainment, by informing of the hydrodynamic forces and particle response. It can be extended to accommodate a wider range of environmental sensors (e.g. for environmental/pollutant monitoring), enabling accurate environmental monitoring which is required to ensure infrastructure resilience and preservation of ecological health.
Further improvements on the device focus on reducing its size and improving the software embedded in the sensors for achieving even lower power consumption to extend deployment time. Finally, transfer of data can be done wirelessly for real time data transfer.