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"Smart Pebble" Design For Environmental Monitoring Applications

Manousos Valyrakis

Edgars Pavlovskis

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"SMART PEBBLE" DESIGN FOR ENVIRONMENTAL MONITORING APPLICATIONS

MANOUSOS VALYRAKIS (1), EDGARS PAVLOVSKIS (2)
(1): Lecturer in Water and Environment, Director of Water Engineering Laboratory, Infrastructure and Environment Research Division, University of Glasgow, Rankine Building, Glasgow, G128LT, UK
(2): EPSRC Research Assistant - Water Engineering Laboratory, Electronics and Electrical Engineering, University of Glasgow, Rankine Building, Glasgow, G128LT, UK

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

INTRODUCTION

The “smart pebble" is a particle instrumented with MEMS sensors appropriate for capturing the hydrodynamic forces a coarse particle might experience during its entrainment from the river bed. A 3-axial gyroscope and 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 of the pebble, so as to achieve a nearly uniform distribution of the mass which could otherwise bias its motion. The “smart pebble" is powered by an independent power supply to ensure autonomy and sufficiently long periods of operation appropriate for future deployment in the field. Post-processing and analysis of the acquired data is currently performed offline, using scientific programming software. The performance of the instrumented particle is validated, conducting a series of calibration experiments under well-controlled laboratory conditions.

DESIGN OF THE INSTRUMENTED PARTICLE

The “smart pebble” is an instrumented particle consists of a hollow spherical particle (shell) and a data logger via which sensor measurements are obtained. The data logger comprises of a memory module, sensor apparatus, a processor and a power supply. A user-friendly development kit is employed.

In particular, a commercial low-cost MEMS (micro-electromechanical systems) incorporating tri-axial accelerometer and tri-axial gyroscope sensors (MPU6050), is utilized to obtain linear and angular displacements from which if sampled at high enough frequencies may help derive the location and forces of the instrumented particle. Data from these sensors are sampled by a microcontroller and written to the external memory. The external memory offers a sufficient storage capacity and compact size, comprises of a micro SD card which can be easily accessed via SPI interface.

A three dimensional design of the shell of the instrumented particle was generated via Solidworks and is shown in Figure 1. The casing is designed so as to evenly distribute the weight of the sensors within the particle so as to reduce any bias while in motion and to represent a homogeneous particle. The microcontroller board fits in place with the MEMS sensors positioned in the center of the sphere to avoid bias due to additional rotation due to any offset.

Two halves of instrumented particle are 3D-printed, using plastic material of sufficient hardness. They have an appropriate “inter-lock” mechanism which securely joins them together while ensuring it is waterproof.

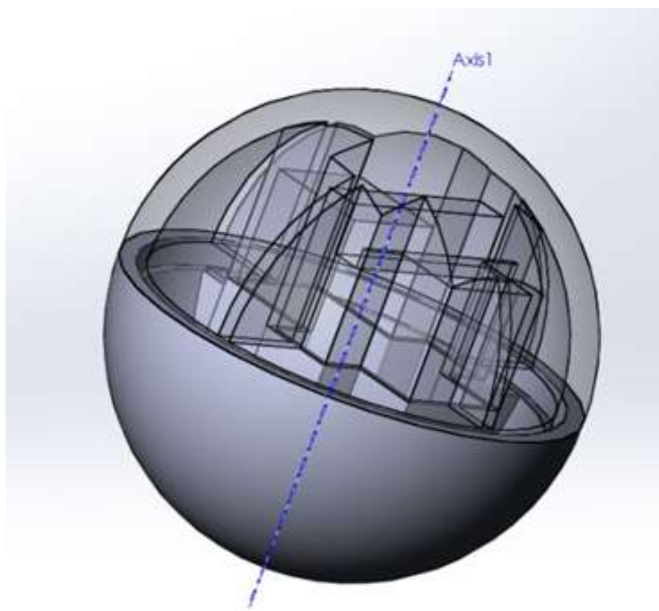

Figure 1. Example of a convergence curve with oscillations

DATA SAMPLING AND ANALYSIS

Acceleration and rotation data are stored in the system’s memory at an average sampling frequency of about 550 Hz. These data (time, three accelerometer and gyroscope readings about each axis) are post-processed offline using an appropriate scientific programming language (Matlab), to derive the three dimensional rotation of the particle relevant to an initial frame of reference. The instrumented particle was calibrated using a high speed camera to monitor its rotation and acceleration in different types of motions: a) a linear descent along an inclined plane, b) 360^o rotation about a fixed point, c) random motion on a vibrational table. Using the data from the particle and the camera, appropriate steps were taken to remove any measurements drifts, and calibrate the sensors. The device is ready to register incipient motion on a rough bed and subsequently track the dynamics of movement and the path taken.

CONCLUSIONS

The “smart pebble" can shed light into the dynamics of particle entrainment, by informing of the hydrodynamic forces and particle response. Using such data along with novel particle entrainment criteria [1], may enhance our knowledge of the dynamics of particle entrainment due to a variety of hydrodynamic flow forcing events. The "smart pebble" can be extended to accommodate a wider range of environmental sensors (e.g. for environmental/pollutant monitoring) towards widening the range of its application, enabling accurate environmental monitoring which is required to ensure infrastructure resilience and preservation of ecological health.

Acknowledgments

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REFERENCES

[1] Valyrakis M., Diplas P. and Dancey C.L., “Entrainment of coarse particles in turbulent flows: An energy approach”, *J. Geophys. Res. Earth Surf.*, Vol. 118, No. 1., (2013), pp 42-53. ISSN 2169-9003, doi:10.1029/2012JF002354.