

行政院國家科學委員會專題研究計畫 成果報告

以水下遙控漂浚機裝配影像儀及射流器探討自然河床載機
制

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以水下遙控漂浚機裝配影像儀及射流器探討自然河床載機制

Development of a tracked underwater ROV equipped with imaging sensors and jet probes for the “in situ” study of live sediment beds

中文摘要

本一年期計畫的研究目的為發展新的方法與工具，藉此觀察河流與近海岸的自然河床輸砂過程。為了往後更深入的研究，本報告提供長期計畫的初步研究成果。本研究採納的方式為在現場裝置履帶水下遙控漂浚機，並在此機器上配備射流器與影像儀。水下遙控漂浚機的功能包括影像即時監測與主動探測附近河床的輸砂過程，甚至在較強水流狀態下，水下遙控漂浚機仍有能力沿著河流或是海底在水下運行。本計畫研究開端著眼於以下四點：(1)設計與建造水下遙控漂浚機平台〔包括儀器機身與驅動能力〕；(2)水下射流裝置的實驗測試與射流現象的數值模擬；(3)發展一套視覺系統可用於水下遙控漂浚機定位與沉積河床量測；(4)利用簡化實驗設備與河流現地觀察來評估新的方法與工具是否可行。至於未來的工作，我們將致力於合併這些研究成果使成為一個完整的操作系統。

英文摘要

The one-year research project documented in the present report launches a long term effort to develop new means for the observation of river and coastal sediment processes. The approach adopted involves the field deployment of a tracked underwater ROV (Remotely Operated Vehicle) equipped with jetting and imaging devices. This ROV will have the ability to move underwater along the river or seabed, even in the presence of currents. Its function will be both to passively monitor and to actively probe near-bed sediment processes. The start-up phase of the programme, supported by a one-year grant from the NSC, focused on the following tasks: 1) the design and construction of the ROV platform (vehicle body and propulsion); 2) exploratory modelling and experimental testing of the underwater jetting device; 3) development of a vision system for ROV positioning and sediment bed observations; 4) preliminary lab and river assessments of the strategy. Future work will seek to integrate these components into an operational system.

Project achievements

1. Vehicle body and propulsion system

The ROV envisioned is a small skid-steered tracked vehicle of approximate dimensions $100 \times 75 \times 50$ cm. It will move at low speeds along a rough sediment bed, submerged underwater and in the presence of medium speed currents. It is to be controlled from the surface, using an insulated umbilical. Its purpose will be to characterize in detail live sediment beds using both passive sensors and active probes. The vehicle platform and propulsion system designed and constructed for this purpose are shown on Figures 1 and 2. Mobility tests and water-proofing of the vehicle remain to be conducted, but all necessary parts of the vehicle were successfully sourced and assembled within budget and within the one-year time frame.



Figure 1. Assembled vehicle body with mounted twin tracks.

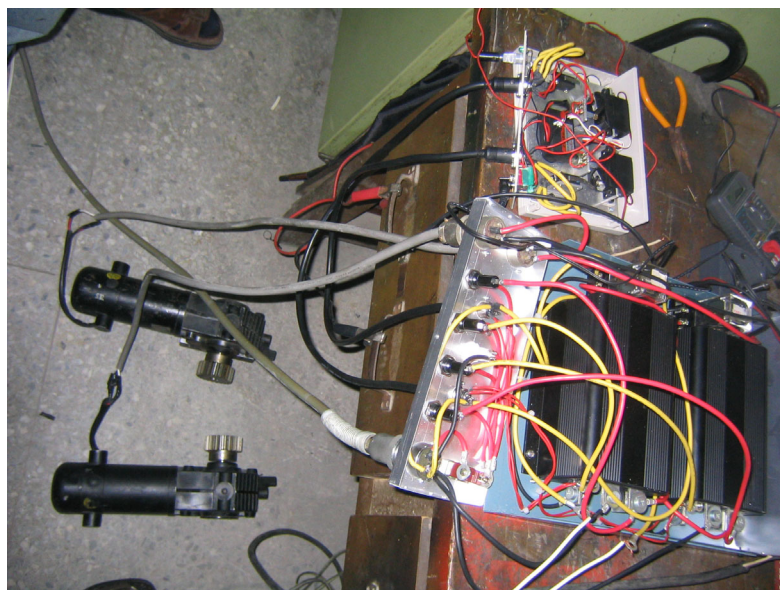


Figure 2. Elements of the propulsion system: twin motors, power supply, and remote control unit.

2. Jetting system

An original component of the proposed ROV design and development is the water jetting probe. The type of interaction between submerged water jet and loose stream bed which the project will seek to exploit is illustrated on Figure 3. Submerged within a water ambient, a turbulent water jet is directed at the loose sand bed. The jet carves a scour hole near the impingement point, carries the sediment outwards and deposits sand further away.

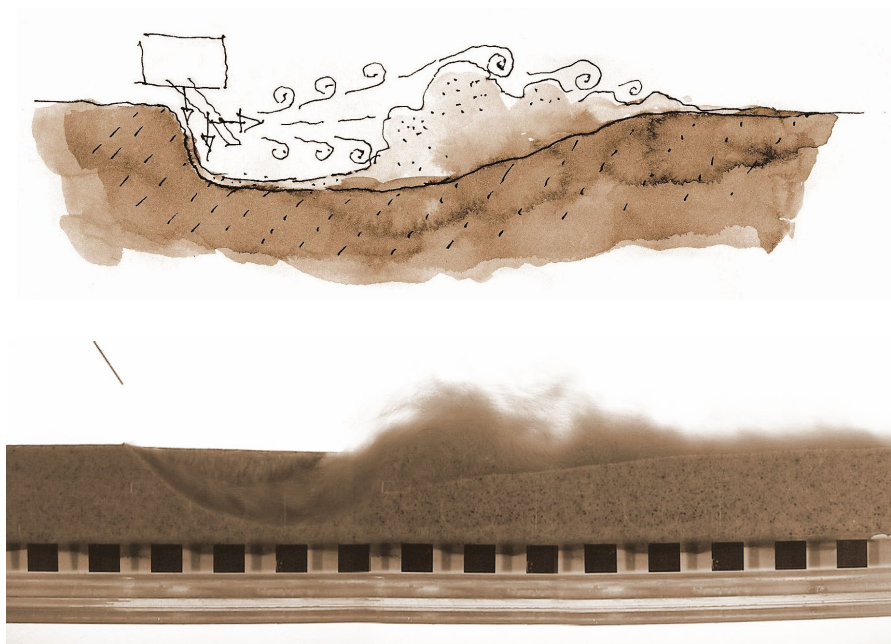


Figure 3. Underwater jet trenching principle (above) and laboratory tests (below).

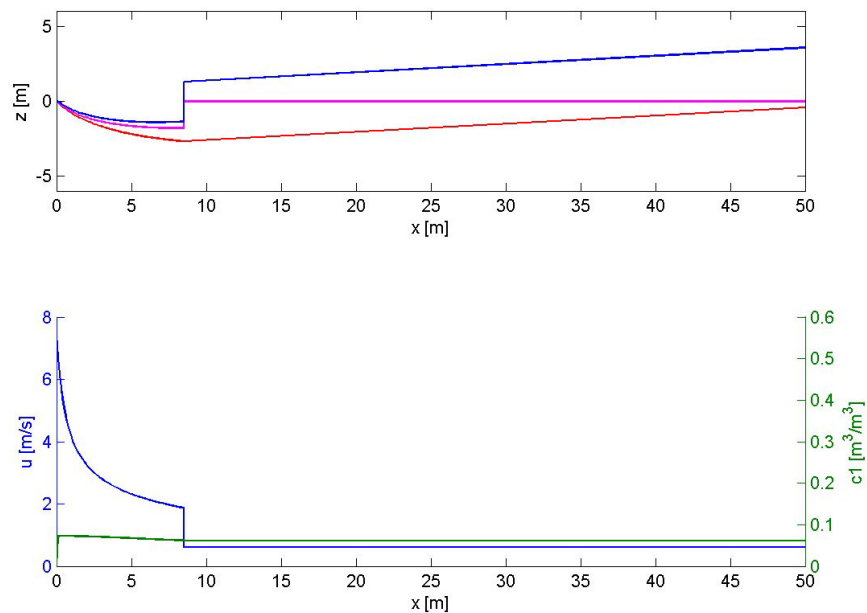


Figure 4. Calculations of trench profile behind a large scale jet trencher.

In order to predict the geomorphic action of the moving submerged jet, we developed a thin layer theory and translated it into a computational scheme. Calculation results are shown on

Fig. 4, for a high-power jet typical of the underwater jet trenchers used in the cable placement and maintenance industry. Small-scale experiments performed in our laboratory to test this theory and guide the design of the ROV jetting probe are shown on Fig. 3 and 5.

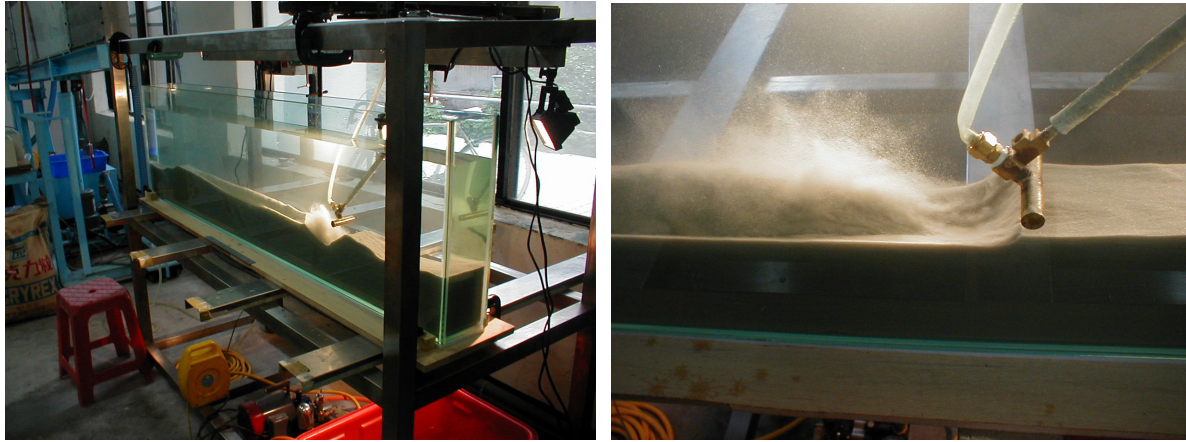


Figure 5. Idealised jet trenching experiments carried out to test the thin layer theory and guide the design of the jetting probe.

3. Vision system

Both to position the ROV and to observe the underwater sediment beds, the approach retained combines multi-camera vision coupled with a laser scan. The laser scan technique originally developed in our lab for topography measurements in small-scale model tests is illustrated on Fig. 6, and results are shown on Fig. 7. To extend this technique to a mobile ROV, two modifications are required: 1) a rotating rather than translating system is needed to scan the surroundings of the ROV; 2) a positioning system is required to know the location and orientation of the ROV during the scan. A test version of a rotating system is shown on Fig. 8.

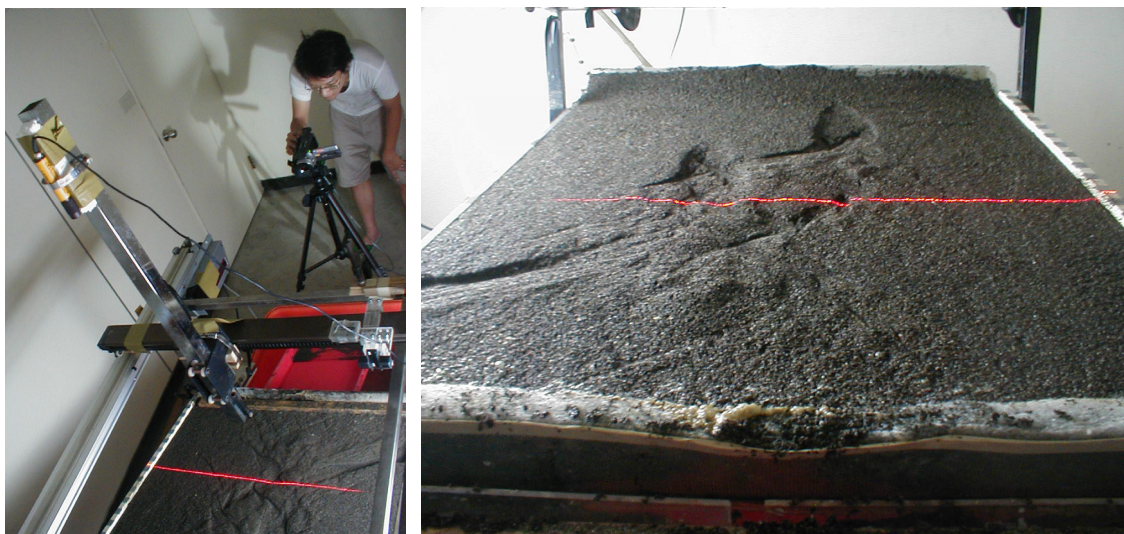


Figure 6. Streamtable and laser profiling apparatus developed in our laboratory for the study of small-scale subaerial geomorphic processes.

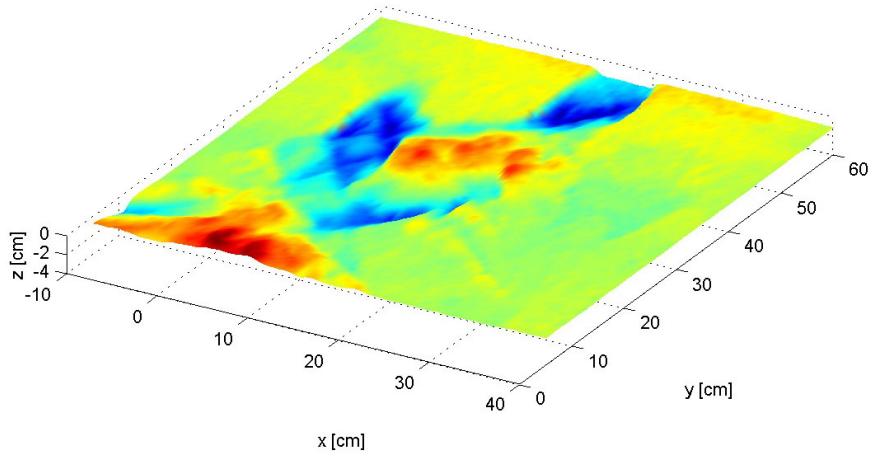


Figure 7. Topography measurements obtained by laser scan.

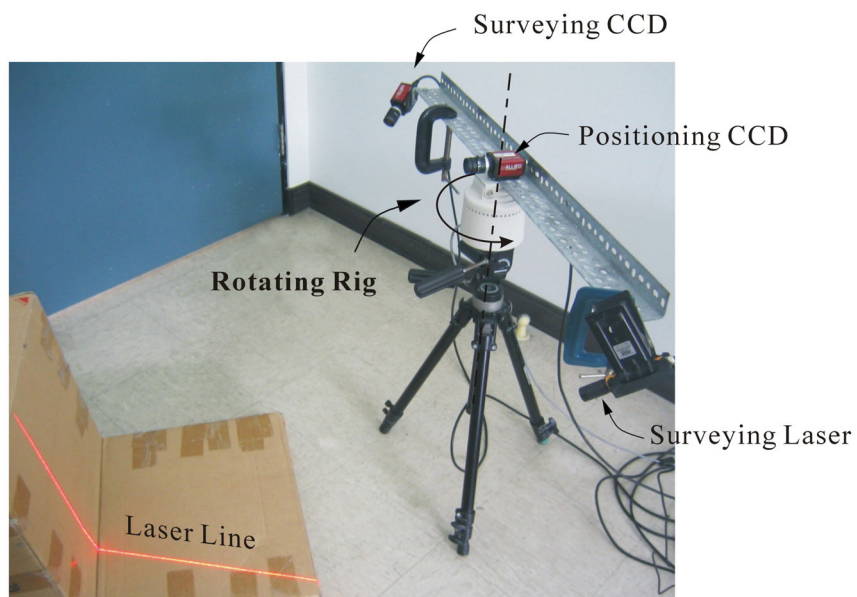


Figure 8. Rotating rig to be mounted on the ROV to simultaneously acquire ROV position and surrounding topography. Preliminary configuration tests.

For both positioning and observations, the rotating CCD camera will assemble photomosaics of the surroundings. To obtain quantitative measurements, rectified mosaics are required. Algorithms for this purpose have been developed and are currently under testing (see Fig. 9).





Figure 9. Top: unrectified mosaic of small river channel eroded by typhoon Morakot; bottom: rectified photo mosaic acquired using rotating positioning CCD. Although unrectified mosaics are sufficient for qualitative observations, rectified mosaics are needed for quantitative measurements.

4. Lab and field assessment tests

In order to conduct preliminary assessments of the strategy, exploratory tests were also conducted in the laboratory and in the field. A small-scale model of the ROV was used to conduct the underwater motion and imaging tests illustrated on Fig. 10. On the other hand, site tests at an upland river were conducted to check that underwater visibility would be sufficient for imaging observations (see Figures 11 and 12).



Figure 10. Underwater operation of the small-scale model in a laboratory water tank. Stereo footage from two underwater cameras.



Figure 11. River site at which underwater visibility tests were conducted.



Figure 12. Frames acquired to test the feasibility of underwater imaging of river beds.

Goals achieved

The goals of the one-year project were to develop and test separate components of the system. All components were assembled within budget and without time overruns. While a number of tests have been successfully performed, some necessary tests remain to be conducted for certain components. Details are as follows.

1) ROV platform

A tracked and skid-steered ROV platform was successfully assembled. The motors/power supply/control system was assembled and tested on the workbench. However the motors remain to be mounted onto the platform, and driving tests on dry land remain to be conducted.

2) Underwater systems

Water-proofing solutions for the vision system were successfully tested in the lab and in the field. Water-proofing of the ROV body and propulsion system has been prepared but not yet tested. Buoyancy elements remain to be added, but this is a relatively simple operation.

3) Vision system

Most components of the vision-based observation and measurement system (cameras, laser lighting, topography reconstruction algorithms, positioning and orientation sensing) have been tried on laboratory test benches. A means of acquiring calibrated, rectified mosaics from a rotating camera was devised. However the vision system remains to be mounted on the ROV platform to conduct dry land testing of the system.

4) Jetting probe system

A testing rig for the water-jetting device was successfully completed, and a series of tests have been performed. Comparisons between experimental results and simulations have already led to refinements of the theory and computational model. This is the most mature component of the system. The tests demonstrate that water-jetting provide a powerful and highly controllable means of probing sediment beds.

Pending some further tests, the various components of the system are basically ready. Future work will focus on integrating these components into an operational system, and on testing the full system on dry land, then under water in a laboratory environment. The long term aim is to deploy the system in field environments.