計畫編號：BE02-00
計畫名稱：智慧型全自主人形機器人之研發
計畫主持人：羅仁權/ 黃漢邦
計畫摘要(中)：

隨著科技的進展，各種相關於機器人的研究也日漸增多，而雙足機器人則為一般學者認為最能克服各種地形的技術，此外為了能夠和人類合作、工作、互動或是幫助人類，新一代的機器人必須設計為類人形之結構，以便能各種建築物中活動自如。於是在此計畫中，我們提出可協助人類並且能和人類互動之類人形機器人，並且研發具溫感觸覺壓力感測陣列之人工皮膚與仿人眼智慧影像系統。

NTU 類人形機器人將會整合雙足、雙手、雙手掌、身軀、頭與立體視覺系統，而此類人形機器人整體將有超過 40 個自由度。

計畫執行第一年度主要是在設計整體類人形機器人的整體架構與機構，及推導類人形機器人的運動方程式，而針對直流伺服馬達控制將設計以 DSP 為基礎的動作控制系統，NTU 類人形機器人的規格如下表所示。

規格	NTU 類人形機器人
重量	60kg
行進速度	0-6km/h
高度	120cm
握力	1kg/hand
制動器	伺服馬達 +諧和式減速機 +驅動單元 +控制器
控制單元	步行/操作控制單元 無線傳輸單元
感測器	足部: 6-軸足部感測器 軀幹: 迴轉儀, 加速計, 電子羅盤
電力	38.4V/10AH(NI-MH)
操作方式	工作站與可攜式裝置
頭	3 DOFs
手臂-肩膀	3 DOFs
手臂-肘	1 DOF
手臂-腕	3 DOFs
雙手臂	7 DOF×2=14 DOFs
手掌	12 DOFs
雙手掌	4 DOFs×2=8 DOFs

腿-髖部	3 DOFs
腿-膝	1 DOF
腿-踝	2 DOFs
雙腿	6 DOFs×2=12 DOFs
軀幹	3 DOFs
整體自由度	40 DOFs

以機器人的功能分類，本計畫可以分成以下五個子計畫：

(1) 類人形機器人之感測器融合與整合
(2) 類人形機器手臂與軀幹之設計與運動規劃
(3) 具溫感觸覺壓力感測陣列之人工皮膚
(4) 仿人眼智慧影像系統之研發
(5) 智慧型全自主人形機器人雙足之研發

在第二年，我們將發展 kinematic 的 NTU 類人型機器人的動態系統，並開發具有超音波感測器、雷射測距儀的運動規劃。此機器人可以利用多重感測融合理論去偵測障礙物、具有抓取即時視覺的 SLAM 技術並應用在導航和路徑規畫方面。在多重感測融合理論，我們預期發展的 NTU 類人型機器人具有適應性融合及整合方法及包含 Dempster-Shafer, Neyman-Pearson 等方法。再者，使用多重感測融合理論去計算及預估電力的狀態。NTU 類人形機器人將開發成具有感測系統模組化的概念。

在第三年，我們將要提出 NTU 類人形機器人的動態系統，我們預期使用分散式控制系統，推導出複雜的動力學方程式，並使用 Zero Moment Poing (ZMP)方法去控制類人形機器人、類神經控制、強健控制(robust control)、滑模(sliding mode)、經由感測回饋訊號去增強學習的演算法以及分析類人形機器人重心的穩定度。最後，類人形機器人將會具有以下的功能，包括導航功能、大樓的室內保全功能、老人與小孩的居家照護、娛樂及教育，或是家庭的服務。再者，將這些發展的技術轉移給相關的企業，提升台灣的機器人技術及產業。

計畫摘要(英)：

In recent years, the needs of robots are gradually increasing with the development of robots. Many researchers and engineers have devoted to constructing different kinds of robots for specific tasks, especially mobile robots and biped robots, which can be utilized in a widespread field of robotics. Moreover, most researchers agree that a biped robot has better

mobility in most rough terrains.

To work, cooperate, assist, and interact with human, the new generation of robots must possess the anthropoid structure that can adequately accommodate itself to the unstructured and sizable environments and interact with people. Hence, an intelligent humanoid robot that can assist and interact with human is proposed in this project. In addition to developing the intelligent system of the humanoid robot, the development of artificial skins and eyes are the kernel of appearance design in this project.

The NTU humanoid robot will be integrated with two legs, two arms, two hands, trunk, head and stereo vision system. There are more than 40 DOFs (Degrees of Freedom) in the humanoid robot.

Specification	NTU Humanoid Robot
Weight	60kg
Walking Speed	0-6km/h
Height	120cm
Grasping force	1kg/hand
Actuator	Servomotor +Harmonic Speed +Drive Unit +Controller
Control Unit	Walking/Operating Control Unit Wireless Transmission Unit
Sensors	Foot: 6-Axis Foot Area Sensor Torso: Gyroscope, Acceleration Sensor, compass and inclimeter
Power	38.4V/10AH(NI-MH)
Operation Section	Workstation and Portable Controller
Head	3 DOFs
Arm-Shoulder	3 DOFs
Arm-Elbow	1 DOF
Arm-Wrist	3 DOFs
Two arms	7 DOF × 2=14 DOFs
Hand	12 DOFs
Two hands	4 DOFs × 2=8 DOFs
Leg-Hip	3 DOFs
Leg-Knee	1 DOF
Leg-Ankle	2 DOFs

Two legs	6 DOFs × 2=12 DOFs
Torso	3 DOFs
Total DOFs	40 DOFs

First year, this project will be focused on design aspects of the overall humanoid robot mechanisms and structures. The kinematical equations of the humanoid robot system will be developed in this project. The DSP-based motion control system will be designed for the DC servomotor of the humanoid robot. The specifications of the NTU humanoid robot are described as the table above.

According to the functionality of the robot, this project is divided into five sub-projects.

(1) Sensor Fusion and Integration of the Humanoid Robot
(2) Design and Motion Planning of the Humanoid Robot Arm and Trunk
(3) Artificial Skin with Integrated Temperature, Tactile and Shear-Stress Sensing Arrays
(4) Development of Human-eye-mimetic Intelligent Imaging System
(5) Development of Legs of an Intelligent Autonomous Humanoid Robot

Second year, we will develop kinematic systems for the NTU humanoid robot, and explores the motion planning using ultrasonic sensors, laser range finders. The robot can detect the obstacle using multisensor fusion and integration algorithm, and investigate the real-time vision-based simultaneous localization and mapping (SLAM) techniques and its application in navigation and path planning for the biped robots. In the multisensor fusion algorithm, we plan to develop adaptive sensor fusion method and incorporate with methods, such as Dempster-Shafer, Neyman-Pearson method etc., for the NTU humanoid robot. In addition, we plan to use multisensor fusion algorithm to calculate and predict a variety of the gravity center of the robot and the power status. The NTU humanoid robot will be developed with modularity concept including the sensory systems.

Third year, we will propose dynamic systems for the NTU humanoid robot. We plan to use distributed control system to deduce the complexity of the dynamic equations, and control the humanoid robot using ZMP method, neural control, robust control, sliding mode and reinforcement learning algorithms according to the sensory feedback signals, and analyze the stability of the gravity center of the humanoid robot.

Finally, the robot will be integrated together so that the proposed humanoid robot can be utilized in guidance service, building and domestic security, elder and child nursing, entertainment and education, or home care services. Furthermore, the developed techniques will be transferred to the related industries and then stimulate the development of the robotics industry in Taiwan.

計畫編號：BE02-01

計畫名稱：人形機器人之感測器融合與整合

計畫主持人：羅仁權

計畫摘要(中)：

類人形機器人可在日常生活中幫助人類生活，為了在日常生活環境中執行許多工作，感測資料的處理是基本且重要，而要開發出多功能的自主人類形機器人是很重要又具有挑戰性的研究課題。類人形機器人在真實世界服務的應用中，必須將物體辨識與路徑規畫系統等整合起來。而這些技術需要透過視覺的自我定位方法來達成導航的目的，並透過物件識別方法達到抓取目標物的目的。要達到這些目的，如果使用了多重感測資料融合的技術，將可提升自動導航與避障的能力。此計畫以此為目標來為台大類人形機器人開發多重感測資料融合為基礎的分散式路徑運動控制系統，即時多重視覺的同時定位與建圖演算法與感測資料融合的分散強健式控制。

1) 多重感測資料融合為基礎的分散式路徑運動控制系統將開發合作式感測器，可為相鄰軸提供相對所需要資料，並將估計值的誤差減到最低，而感測器融合技術是分散式可有效降低運動軸的運算負擔。
2) 多重視覺同時定位與建圖演算法在機器人研究領域中是基礎又很複雜的技術，我們將開發的 SLAM 技術會由環境的預測器先對機器人尚未探索的區域產生合理的假設資料。而預估式 SLAM 技術對鄰近的區域強迫產生假設資料是合理的，又可即時提供給機器人對未探索的區域使用。要將預估式 SLAM 技術應用的話，必須考慮兩個重要的基本要求：即時處理與簡潔地圖表示。探索地圖的工作對即時運算的需求很高，而簡潔地圖表示可使機器人很容易區別是否探索過的地圖，而我們將使用粒子濾波器為基礎來處理預估式 SLAM 技術。

3) 感測資料融合的分散強健式控制：使用與控制器相同數目的感測資料融合濾波器，可讓機器人成為完全分散式系統。而在機器人的控制上所需的控制器數目可依需求來決定。在機器人的導航技術中，至少需要一個控制器負責導引機器人到達目的，各自的控制器可直接或透過資料融合處理器來接收感測器的資料，而此資料融合技術對環境資料的表達將可大幅減少錯誤率。

即時式路徑規畫系統、智慧型同時定位與建圖技術與分散式控制系統將整合入台大類人形機器人來達成各式的工作，如導引服務、保全、照護、娛樂與教育。

計畫摘要(英)：

Humanoid robots are expected to assist human activities in daily life. In order to achieve the tasks for daily environment usages in real world, sensory information is essential. Thus, the development of general-purpose autonomous sensory based behavior humanoid robot system is an essential and challenging research issue.

The humanoid robot system for real world service applications must integrate with object recognition and motion planning systems. These requirements involve the vision system capable of self-localization for navigation utility and object recognition for manipulation tasks, while communicating with the motion planning subsystem. The multi-sensor fusion control increases the ability of autonomous driving and obstacle avoidance of the robot. This project will develop multi sensor fusion based distributed motion control system, real time multi vision based simultaneous localization and mapping(SLAM) techniques and sensor fusion based distributed and robust control mechanism for NTU humanoid robot.

1) Multisensor fusion based distributed motion control system will develop cooperative sensors provide relative posture estimates between neighboring axles, and minimize posture estimate error. These sensor fusion methods are distributed for scalability and reduced axle level computational burden.
2) Multi-vision based simulatenous localization and mapping (SLAM) is a fundamental and complex problem in robotics research. Our SLAM method has an environmental-structure predictor to generate

hypotheses of unexplored regions before the mobile robot actually explores them. Specifically, the predictive SLAM focuses on unexplored regions that are in the neighborhood of the explored regions because they are the next exploration targets, and the mobile robot can use the information in these unexplored regions immediately.

1) To implement the proposed predictive SLAM, we need to consider two important requirements: real-time processing and a clear map representation. The real-time processing is usually required in an exploration task, and the clear map representation allows a robot to easily distinguish explored and unexplored regions. Here, we use an particle filter as the backbone of predictive SLAM
2) Sensor fusion based distributed and robust control mechanism, the number of local filters is equal to the number of controllers involved in the fusion. Thus the system is completely distributed. The set of controllers used in the control architecture depends on the specific application. In mobile robot navigation, at least one controller responsible for guiding the robot to the destination point, which receives information from the internal sensors of the robot, should be present. The individual controllers receive the sensory information they are designed to deal with, either directly or through a fusion engine. Such data fusion is used either for a better environmental representation or for noise reduction.

The real time motion planning system, smart simultaneous localization and mapping techniques and distributed control system will be integrated into NTU humanoid robot to achieve different kinds of tasks, such as guidance service, building security, elder and child care, entertainment and education.

計畫編號：BE02-02
計畫名稱：擬人形機器手臂與軀幹之設計與運動規劃
計畫主持人：黃漢邦
計畫摘要(中)：

為了發展能單獨幫助人類工作、與人類合作作業、協助人類工作及與人類互動機器人，新一代的機器人必須擁有可以在未知環境中，

能適當調整自己動作並協助人類的控制系統、智慧型運動規劃系統及與可與人類互動的仿人結構。此外，在人類習慣與「人」互動的情況下，擁有類似人類雙手的機器人不但能適應未知的人類環境，且可以適當的與人類互動。由於擁有良好設計的擬人形半身機器人系統可以輕易的安裝在為不同目的而設計的特定機器人平台上面。因此，本計畫將特別著重於設計一個能協助人類並與人類互動，且具有雙機械手臂的擬人形半身機器人系統。本計畫可分為三大部分並分三年完成，分別是：

(1) 具有雙機械手臂之擬人形半身機器人機構設計: 包含雙機械手臂、雙多自由度機器手及擬人型軀幹之機構設計與發展。
(2) 具有雙機械手臂之擬人形半身機器人之控制系統設計: 包含雙機械手臂、雙多自由度機器手及擬人型軀幹之控制系統設計與發展。
(3) 具有雙機械手臂之擬人形半身機器人之運動規劃系統設計: 包含雙機械手臂、雙多自由度機器手及擬人型軀幹之運動規劃系統設計與發展。

所發展的台大半人型機器人(NTU Torso Humanoid Robot)將擁有雙臂、雙手、軀幹，同時可在人類環境中與人互動。本計畫所發展的智慧型控制理論與運動規劃理論，使機器人可執行抓、握、搬運東西等行為，並自動避免與環境中的障礙物碰撞。最後，與決策系統與行為學習理論整合，使機器人具有多用途且能應用在不同領域，像是導覽、建築、居家保全、年長者及孩童看護、娛樂、教育及軍事用途等等的全自主式的智慧型伙伴。

計畫摘要(英)：

In order to work, cooperate, assist, and interact with human, the new generation of robots must possess an anthropoid structure, intelligent control systems, and motion planning systems so that the robot can adequately accommodate itself to the unstructured and sizable environments and interact with people. This project is aimed to develop a NTU torso humanoid robot. The entire project is mainly divided into the following three parts and will be completed within three years.

(1) Mechanism Design of the NTU Torso Humanoid Robot

The mechanism is crucial to the performance of a torso humanoid robot. It involves in mechanism design, the arrangement of actuators and sensors, the distribution of masses, the analysis of the kinematics and dynamics, the compromise between safety and performance. Hence, this project is aimed to design and construct the mechanism consisting of two humanoid robot arms, two multi-DOF robot hands, and multi-DOF trunk for human-robot interaction.

(2) Control Systems of athe NTU Torso Humanoid Robot

Since the torso humanoid robot has many DOFs and executes complex motions, how to construct a fast and highly efficient coordination control system of the torso humanoid robot will be an important issue. The control system will be divided into several sub-systems and designed for the different purposes. Namely, we will individually develop humanoid robot arms, hands, and a trunk control systems to match the specified situations that each one may meet.

(3) Motion Planning of the NTU Torso Humanoid Robot

Some of the most significant challenges for autonomous robots lie in the area of automatic motion planning. We will individually develop the special and intelligent motion planning systems for the humanoid robot arms and hands to achieve the specified and desired tasks in the physical world subject to physical laws, uncertainty, and geometric constraints.

By integrating the mechanism, control and motion planning, the developed NTU torso humanoid robot will be operated smoothly and stably. It can execute some complex motions, such as carrying the object to the desired location or assisting human to do some heavy tasks. In addition, the robot can not only grasp the specified object but also avoid the obstacles in an unknown environment in the meantime. A decision making system and behavior learning system will be included in the motion planning systems to make the robot more autonomous.

計畫編號：BE02-03

計畫名稱：具溫感觸覺壓力感測陣列之人工皮膚

計畫主持人：楊燿州

計畫摘要(中)：

本研究主要的目標，將開發出可撓式觸覺與剪應力感測陣列，並將展示其可用於機器人上之人工皮膚。首先，我們提出一創新之高敏感電容式感測器之結構的設計。這個新式的設計，除了製造程序簡

易，更具有高可靠度的特性。在研究中，所製造出的人工皮膚是利用微製程技術所製造而成。其組成是由 PI 基材及聚二甲基矽氧烷（PDMS）層所構成。其中 PDMS 層沈積於已定義圖形之金屬層，來作為於電容式感測陣列當中觸覺與剪應力感測元件。PDMS 的成型是由 SU-8 厚膜光阻之母模所翻模而成。而 PI 基材上的雙層金屬導線及感測電極則由微蝕刻的方式所製作完成。電容式感測器利用量測聚二甲基矽氧烷薄膜變形，來感測施加外力變化。在每一個剪應力感測器當中，則有四個電容感測器，能夠將接觸力轉換成正向壓力或剪應力。然而，為了能精準感測剪應力變化，剪應力感測單元的凸塊與觸覺感測器之間的支撐圓柱也被應用於設計當中。感測陣列中，亦將使用少量的溫度感測晶片來感測皮膚周遭的環境溫度。研究中亦將開發相關的掃描讀取電路，並架構量測平台以對人工皮膚的各項特性做探討。針對機器人的應用，不同的人工皮膚大小與感測器種類的設計與應用將進行介紹。掃瞄電路的設計與製造亦將應用於所相對應的感測器陣列。

計畫摘要(英)：

Recently, the development of humanoid robots has received significant attention. In order to ensure effective and safe interactions between robots and humans, intelligent sensing capabilities for robots are critical. Therefore, this requirement has boosted the demand of artificial skins in robotics research field. The primary purposes of artificial skins are to realize the information exchange between robot and human beings as well as environment, and to serve as the sensing systems to avoid damages to humans or robots. The basic sensing capabilities of an artificial skin include the sense of touch, the sense of temperature, and so on. For a typical artificial skin, a large number of sensing elements, such as tactile sensors and temperature sensors, are required to be implemented on a sheet-like flexible structure of about few hundred cm2 area which will have enough flexibility to cover a three-dimensional surface. In this work, we will develop a flexible capacitive tactile and shear-stress sensing array, which will serve as the artificial skin for robot applications. A novel design of high-sensitive capacitive sensor structures is proposed. The design is highly reliable and highly manufacturable. The proposed artificial skin is fabricated by using

micromachining techniques. Polydimethlysiloxane (PDMS) layers deposited with patterned metal layers will be used as the capacitive sensing arrays for tactile and shear stress sensing. A novel method for fabricating tactile and shear-stress sensing element is also proposed. Each tactile sensing element consists of two parallel-plate capacitors with a common electrode. This design can effectively reduce the complexity of the capacitor structure of each sensing element. Also, because of the elimination of the long metal interconnect on the flexible PDMS layers, the reliability of the device can be greatly enhanced. The design of capacitor structure for the shear-stress sensing element is also similar to the structure of the tactile sensing element, while the top surface of the shear-sensing elements will embedded with tiny bumps which significantly improve the performance of shear-stress sensing. For each skin, a discrete temperature chip will also be integrated. The corresponding scanning circuit for each sensing array will also be designed and implemented. Furthermore, the developed artificial skins will also be deployed on the robots developed in this integrated project. Many configurations of the skins, such as array sizes, skin sizes and sensor types, will be designed and implemented according to the robot applications. For example, high-resolution and small-area skins will be used for the fingers of the robot, while large-size skins will to used for the robot trunk or arms. Also, shear-stress sensing skins will be deployed on the fingers to test the gripping capability of the robot hands.

計畫編號：BE02-04

計畫名稱：仿人眼智慧影像系統之研發

計畫主持人：施文彬

計畫摘要(中)：

本子計畫擬發展應用於智慧型機器人之人工眼睛，此人工眼睛為一智慧影像系統，其驅動機制模擬人眼，使其光學變焦與光圈範圍與人眼規格相當。此影像系統包括一金氧互補半導體影像感測器陣列以及一適性光學系統。此光學系統可仿照人眼，由人工水晶體與人工瞳孔即時調整焦具與光圈，此光學系統亦具有可撓性，因此可輕易安裝於仿人機器人；本計畫將利用微機電技術將此光學系統微型化，影像感測器陣列將用以擷取透過此光學系統的影像。本計畫將同時發展嵌

入式系統，用以進行影像識別與光學系統的控制。

本計畫將設計與製作與人眼相近的人工水晶體與人工瞳孔，瞳孔的直徑與水晶體的焦距可以獨立調整，用以控制影像感測晶片上的成像。本計畫將採用聚二甲基矽氧烷作為水晶體材料，水膠作為驅動瞳孔與水晶體的致動器，水膠的體積將依食鹽水濃度與靜電場強度產生變化，水膠具有生物相容性，因此本計畫產出的人工瞳孔與人工水晶體將可進一步改良提供生醫應用。

計畫摘要(英)：

This project is proposing to develop artificial eyes for the applications of intelligent robotics. The proposed artificial eye is an intelligent imaging system inspired by the structure of human eye. This imaging system consists of a CMOS image sensor array and an adaptive optical system. The pupil and lens of the optical system can be in-vivo adjusted as human eye does. It is also flexible as human eye to be easily implemented on humanoid robots. This optical system will be miniaturized using the technology of microelectromechanical systems (MEMS). The COMS image sensor array detects images through the optical system. An embedded system will be developed for image recognition and feedback control of the optical system. This project is multidisciplinary. It integrates the domain knowledge from solid mechanics, microfluidics, polymer physics, optics, micromachining, information science, control, semiconductor physics, and robotics.

The presented device is developed to imitate human eye which can adjust the lens focus and the pupil diameter independently to control the definition of optical image refracted on the retina. In this project, we will use the hydrogel which is sensitive to NaCl concentration and electrostatic field as the actuator to enhance biocompatibility. PDMS will be used as the lens material. A tunable artificial pupil will also be added on to the device.

計畫編號：BE03-00

計畫名稱：基礎建設多重災害先進模擬與實驗技術之研究

計畫主持人：楊德良

計畫摘要(中)：

近年來台灣飽受天然災害之苦，每當颱風過境或是地震發生之後，橋樑、高架道路等結構物的基礎，都可能因為洪水沖刷、土石流及土壤液化等現象，遭受到嚴重破壞而有安全之虞。影響這些天然災害現象的因素很多，但學術的關鍵議題在釐清流體與固體的交互作用與其在河床沖刷面、土石流內部及液化土壤層內衍生之重要機制。因此，要了解天然災害對結構物的影響，需要連結多個尺度的研究：從局部物質之間的行為，至整體結構物的反應。本計劃擬藉由發展先進模擬及感測技術，搭配實驗室及現地感測結果的驗證，深入探討流固耦合的多尺度行為與釐清其在天然災害扮演的重要機制。

本計劃延續第一期「利用創新實驗技術及科學計算方法探討結構物受地動力反應」的研究成果，於第二期研究發展成七項子計畫，將研究重心專注於模擬計算、實驗及現地感測三個方面。於模擬計算方面，本計劃整合擁有計算流體力學（子計畫一）、分子動力學（子計畫六）以及結構破壞模擬（子計畫七）的團隊，發展流體、固體交互行為及對結構物影響的創新模擬技術。於實驗室實驗方面，採用創新影像技術，分別以巨觀的角度從外部觀察土石流的流動行為（子計畫四），及微觀的角度觀察當流體內部有許多顆粒時的力學行為（子計畫二）。而於現地感測方面，發展先進感測網路，應用於橋樑基礎監測（子計畫三）及結構物破壞（子計畫五）等真實情況，並藉由與實際量測結果比較，驗證本計劃所提出的感測技術。

本計劃著眼於台灣近來所遭受的天然災害及結構物破壞等問題，提出結合模擬計算、實驗及現地感測等創新理論與技術。透過此研究，除可持續強化本研究團隊在國際學術的領先地位外，也希望以此先導研究為基礎，了解並協助我們解決台灣目前遭遇的天然災害問題。

計畫摘要(英)：

In hazard-prone Taiwan, bridges, elevated roadways and other infrastructures sited across and along rivers are subject to a variety of complex risks. These include flood scour, debris flow surges, and earthquake-induced soil liquefaction. The phenomena involve local interactions between liquid and solid constituents along erodible riverbeds, in debris flow slurries and within liquefied soil strata. Characterization of the corresponding hazards thus requires bridging across multiple scales, from the local material behavior to the overall

structural response. The proposed integrated research seeks to address these issues by developing novel modeling and sensing technologies, and testing them in both laboratory and field conditions. The project builds on a current integrated research on the "Characterization of geodynamic forcings and structural responses using novel instrumentation and computing strategies". It will involve a combination of computational, experimental, and field efforts, structured in 7 sub-projects. Three research groups with backgrounds in computational fluid dynamics (sub-project 1), molecular dynamics (sub-project 6) and structural damage simulations (sub-project 7) will be integrated to pursue new means to model the behavior of liquid-granular media and their influence on structural elements. Two programs of laboratory experiments will be respectively conducted to probe the macroscopic dynamics of debris flow surges (sub-project 4), and the micromechanics of highly concentrated liquid-granular flows (sub-project 2), using novel external and internal imaging techniques. Finally, two innovative efforts will be pursued to develop, test and deploy advanced networks of sensors capable of monitoring bridge foundation scour (sub-project 3) and structural damage (sub-project 5) in actual field conditions. With insights from modeling efforts and laboratory experiments, and reality checks provided by field measurements, the integrated project is expected to produce original scientific findings relevant to engineering applications in Taiwan.