SMART MOBILITY RESEARCH
AT BGU

The Center for Integrative Transportation Innovation
SMART MOBILITY RESEARCH
AT BEN-GURION UNIVERSITY OF THE NEGEV

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The Center for Integrative Transportation Innovation

Ben-Gurion University of the Negev operates the CITI (Center for Integrative Transportation Innovation), a research center dedicated to smart integrated transportation. The Center is comprised of about 40 senior researchers from a range of faculties and disciplines at the university.

The researchers are involved in a range of aspects of transportation systems, such as urban and metropolitan planning, road safety, automatic/autonomous driving, V2X, information security and cyber security, advanced learning methods (AI, Deep Learning, Distributed Agent Computing, Behavioral Programming, etc.), sensors, big data (advanced statistical methods, information mining, visualization), mathematical models (performance research, optimization, game theory), energy solutions (alternative fuels, electric energy), mechanical design of vehicles (BGRacing team), economics (incentives and their implications) and more.

The above list illustrates the CITI’s comprehensive approach, which strives to utilize the capabilities developed at BGU’s Faculty of Engineering (which includes 13 departments and units, engaged in all fields of engineering) as well as in the faculties of Management, Natural Sciences, Life Sciences and the humanities and social sciences.

This brochure introduces CITI’s researchers, and the subjects of their diverse research activities related to transportation fields.

We invite you to contact us and explore possible cooperation.
Traffic-signal-to-vehicle communication applications and their impact on driver behavior

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OBJECTIVE
Advancement in communication technologies enables digital transfer of information about their current status from traffic signals to in-vehicle devices (e.g., smart phones). This information can be used to assist drivers with the decisions they need to make when the green phase ends, or to prepare for driving before the green phase starts. The purpose of this research is to examine the effects of these applications on driver behavior in an on-road driving experiment.

DESCRIPTION
The communication between traffic signal controllers and vehicles is implemented in two primary ways: through cellular connection, and through Dedicated Short Range Communication (DSRC). The latter option is based on technology developed by Autotalks. In the experiment, 100 subjects drive along a prescribed route in Beer-Sheva, with and without the system, and their behavior is monitored.

APPLICATIONS & PRODUCTS
This empirical research project is practically-oriented, with direct application to products that support the driving task, such as navigation applications, advanced driver assistance systems (ADAS), safety applications, and more. The communication channel can also be used for additional products, in which the traffic signal responds to the information provided by surrounding vehicles.

RELEVANT PUBLICATIONS

Expertise
Quantitative transportation analysis, transport models, traffic safety, ITS
At present work focuses mostly on deep learning methods.

**Topics of interest include:**

- Phenomics: solving complex visual discrimination problems in agricultural settings
- Autonomous robotic kit assembly with pose estimation networks and deep reinforcement learning
- Ultra sound imaging with deep learning and inverse problems in general
- Understanding and visualization of hidden layers in deep networks
- Visual object tracking

In the past, was a researcher in General Motors Research, working on active safety features and toward autonomous driving.

**Has written papers about:**

- Object detection and pose estimation, specifically: pedestrian detection
- Visual object tracking, specifically: vehicle tracking
- RADAR target classification
- Lane detection

**RELEVANT PUBLICATIONS**

- See the home page at: https://sites.google.com/site/aharonbarhillel/
- Google scholar citation: https://scholar.google.com/citations?user=x4GIt3IAAAAJ&hl=en
Serious games for positioning the transportation of tomorrow

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OBJECTIVE
My research aims to utilize smart mobility solutions, based on ICT architectures, to shape travel behavior and achieve social and sustainability goals in smart cities. My objectives are to understand how emerging technologies can influence human spatial behaviors (choice of location, mode, route, time of travel) and how this behavior interacts with the performance of the transportation system as a whole. I also use big data from public sources to study travel patterns and dynamics, including: smartcards, mobile phones, automatic vehicle locations for public transit and bike-sharing.

DESCRIPTION
I established and lead the GAMESlab, where we study the behavioral and operational dynamics of transportation systems based on three methodological pillars: big data, serious games (including virtual reality) and agent-based simulation models. I am PI in an ISF grant investigating the use of travel information and incentives strategies to promote the emergence of cooperation for the optimization of road traffic. Another ISF grant applies simulations and games to understand parking choice dynamics and find optimal pricing and zoning. Another project is aimed at understanding future traveler shifts towards ridesharing in autonomous vehicles using surveys, games and simulations. In research projects related to transit systems, I use big data analytics, including: smartcard analysis for extracting spatial and temporal travel behavior patterns, Automatic Vehicle Location for transit service reliability analysis and smart transit network design based on mobile phone records.

APPLICATIONS & PRODUCTS
• System-optimal vehicle routing
• Parking pricing and optimal zoning
• Public transportation reliability and usage
• Adaptive public transportation
• Adoption of shared autonomous vehicles

RELEVANT PUBLICATIONS
**OBJECTIVE**
My main research interests are human factors in traffic safety. I am mostly interested in understanding and modeling driver behavior under various conditions such as driver distraction, automated driving, and stress and fatigue, as well as understanding the effect of age and driving experience on drivers’ performance. I am also interested in understanding the interaction between drivers and automated vehicles and in-vehicle technologies, including issues such as transfer of control, driver comfort and behavioral adaptation.

**DESCRIPTION**
The main topic studied currently in the Human Performance Evaluation Lab is drivers’ interactions with fully autonomous and partially automated driving. Some of the studies focusing on fully autonomous driving deal with the question of how autonomous vehicles should behave so that passengers of such vehicles will accept and trust the technology and will feel comfortable and safe using such vehicles. Our studies on partial automation focus on better understanding how drivers adapt to new technologies and how well they perform when manual driving is required.

**APPLICATIONS & PRODUCTS**
We are interested in designing scenarios and experiments that will allow us to optimally investigate the interaction between drivers, the traffic environment and new continuously developing in-vehicle technologies.

**RELEVANT PUBLICATIONS**
The effects of in-cabin music on driver perception and vehicular control

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Expertise
Use of music in automotive branding, effects of music on driver behavior and vehicular performance

OBJECTIVE

- Music applications for branding automobiles.
- We conduct empirical and applied research concerning the effects of music on driver behavior and vehicular performance. The studies employ driving simulators and on-road demonstrations.

APPLICATIONS & PRODUCTS

- Model for automotive music branding based on engineering design language.

RELEVANT PUBLICATIONS

Development of autonomous systems using script-guided languages

Prof. Achiya Elyasaf
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Expertise
Software engineering, Internet-of-Things

OBJECTIVE
I am interested in the development of a simple contextual language and a computation model for modeling reactive systems for autonomous vehicles, traffic management, the Internet-of-Things, and more.

DESCRIPTION:
I am working on a model that allows visual specification of how systems interact and react to the environment. The specification is then translated to a functioning reactive system. Because the model is built by weaving independent scenarios (a.k.a., behavioral-programming), programmers can easily build bugless complex behaviors (as our experimental research shows).

Consider, for example, a requirement to turn off the lights of an autonomous car if the outside light level is above a threshold $t$. Another requirement, though, may forbid turning off car lights during the winter. Our approach allows for specifying these requirements independently, while weaving them at runtime.

Fig. 1 The two independent scenarios are synced during runtime

RELEVANT PUBLICATIONS

APPLICATIONS & PRODUCTS
Our model is aimed at a reactive system and is currently used in developing complex systems, such as smart buildings, satellites, and safety-assistance systems for cyclists.
Autonomous vehicles

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OBJECTIVE
Provide know-how and solutions in all areas related to Autonomous Robotics. Specific areas of research include: autonomous platforms, computer architecture, control, image and signal processing, neural networks and fuzzy logic, electrochemical processes, robotics, biomedicine, biotechnology and biosensors.

DESCRIPTION
The Laboratory for Autonomous Robotics was founded in 1998. Due to the complexity and interdisciplinary nature of autonomous robotics, researchers and students from different disciplines work in close collaboration, combining the practical and the theoretical in diverse approaches to robotics science. The LAR has made great research achievements in autonomous vehicles, defense, space-related robots, cognition, computer vision and graphics and anthropomorphic robots. Autonomous vehicles include unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV), unmanned sea and underwater vehicles (UUV). The LAR is a member of Team Avant-Guardium in the DARPA Urban Grand Challenge and in DARPA’s Robotics.

Recently, LAR developed the Hydro Camel I & II, the first Israeli autonomous submarine. Further developments include the Intelligent Vehicle Operator (IVO) and FIND, a central vascular access solution. For the past four years LAR’ researchers conducted basic and applied research in UUV, UAV, UGV and instrumentation technologies relevant to defense, industrial, transportation, biomedicine and oceanography tasks.

APPLICATIONS & PRODUCTS
LAR has extensive experience fusing basic research with practical systems. This capability has enabled producing complete systems and the creation of three spin-off companies.

RELEVANT PUBLICATIONS
OBJECTIVE
I’m interested in designing optical and millimeter wave efficient and secure imaging, lidar, and communication systems between vehicles themselves (V2V) and between vehicles and infrastructure (V2I), as well as pedestrian and other object avoidance systems.

APPLICATIONS & PRODUCTS
High speed active and passive imaging can be used to prevent collisions with other vehicles and pedestrians, as well as other objects. We are developing ultra high speed 3-dimensional imaging and wireless mm wave communication systems that can be used for such purposes.

RELEVANT PUBLICATIONS
OBJECTIVE

• Issue an early warning of a failure expected in certain systems or subsystems of an individual vehicle with Telematics-based sensory data and warranty failure data.

• Predict failures expected in certain systems or subsystems of an individual vehicle beyond the warranty period from a very limited amount of post-warranty failure data.

• Predict certain important values (e.g. voltage, pressure, etc.) in an individual vehicle.

DESCRIPTION

Prof. Mark Last and his team worked on a joint project with the General Motors India Science Lab during which they developed:

1. An initial version of the Early Warning Algorithmic Tool using a fuzzy logic algorithm, which is capable of detecting positive and negative shifts in time-to-failure and mileage-to-failure distributions from warranty data.

2. Various prediction algorithms, including decision-tree, single-target and multi-target Info-Fuzzy Networks (IFN and M-IFN), Naïve Bayes, and MetaCost, were applied to GM Telematics-based sensory data. These were then evaluated on the basis of the trade-off between accurate prediction of a critical failure (“true positive rate”), “false alarm” rate, and the size of each model (number of prediction rules). The M-IFN construction algorithm produced a compact and interpretable model of 14 rules estimating the probability distributions of two target attributes (Battery Failure and Time to Failure).

3. Four different failure types of warranty claims were used to build multi-dimensional failure prediction models. We developed a new failure probability estimation algorithm, which automatically chooses the best subset of discrete and continuous predictive dimensions, as well as the best number of equal-size intervals for each continuous predictive dimension.

APPLICATIONS & PRODUCTS

A predictive maintenance system, which can be installed on any autonomous or non-autonomous vehicle.

RELEVANT PUBLICATIONS


OBJECTIVE
Understanding the interaction and behavior of multiple agents – humans or otherwise – in an intricate environment.

DESCRIPTION
Using game-theoretic analysis, I examine what motivates the behavior of agents (for example, choosing a particular route to their destination), and use decision-making models to see how they adapt their behavior to various incentives.

APPLICATIONS & PRODUCTS
Analysis of routing structure and its load under various behavioral assumptions.
Incentives design to entice particular desired behaviors.

RELEVANT PUBLICATIONS
OBJECTIVE
Advancing cutting-edge fundamental and applicative research in power conversion, energy storage and electronics miniaturization techniques, with the goal to achieve an integrated transportation system in support of higher quality of life and a cleaner environment. With a special emphasis applied to productization and manufacturability of the concepts.

DESCRIPTION
Transportation electrification is an important global trend. The implications are broad, spanning several domains: environmental, social and technological.

The PEMIC Center presents the facilities, equipment, and highly trained personnel for carrying out research in the field of Transportation Systems Integration. The experience and background in industry collaboration of the key personnel, enable the advancement of research towards application in a product, i.e. building in-house laboratory prototypes.

The Center includes state of the art measurement equipment, high/low voltage/current sources, soldering and design capabilities, IC design software and PDKs of several foundries.

APPLICATIONS & PRODUCTS
• Wireless power transfer in continually moving environments: VR helmets, vehicles, robots, drones, etc.
• Fast charging of battery powered equipment
• Electromagnetic payload transportation
• Battery balancing and optimization for lifetime and performance benefits
• IC design analog and digital, converter miniaturization
• Power management

*Check PEMIC website for more information
OBJECTIVE

Apply machine learning to learning the routing schemes of drivers during different parts of the day/week in order to develop generic and easy to compute centrality measures for transportation networks.

DESCRIPTION

‘Routing Betweenness Centrality’ algorithms rely on arbitrary probabilistic loop free routing strategy in order to compute the centrality of nodes, links, or groups thereof. Such a scheme can be represented as a function which outputs the probability of a driver taking a specific turn given the properties of the junction, the roads, his final destination and contextual information. Some of these properties may include centrality indices computed using traditional methods. Such a probabilistic routing function can be learnt using standard machine learning algorithms given a training set of driver routes. These routes can either represent the real measured routes or be computed through traditional (heavyweight) traffic assignment algorithms. Once the probabilistic routing function is devised, Routing Betweenness Centrality can use it to efficiently compute the coverage of any set of deployed monitors or optimize their deployment.

APPLICATIONS & PRODUCTS

• Traffic monitoring
• Camera / radar placement
• Optimization of police patrols

RELEVANT PUBLICATIONS

OBJECTIVE
Developing models that explain pedestrian movement and activity in urban space.
Finding ways to improve sense of well-being and safety for pedestrians on urban streets.

DESCRIPTION
My research concentrates on making streets into multi-functional entities capable of supporting social and economic life in cities. We work on both configurational models, modeling how the network of streets shapes human movement, which in turn influences other social and economic aspects of the city, and perceptual and spatial models looking into how the local environment influences choice of movement path, and the sense of well-being while walking or engaging in other activities in public space.

RELEVANT PUBLICATIONS
Dr. Rosenzweig’s research focuses on the driving behavior of consumers, and the way it is affected by policy measures. For example, her research found that a policy that incentivized consumers to buy energy-efficient cars, effectively caused a rebound effect, that is, it increased the kilometers traveled.

A second project explores the mechanism that may underlie increased driving. This research suggests that presenting a pollution scale that reveals the purchased car’s pollution rating may cause a "licensing effect": the consumer may feel that she has done good by buying a car with an environmental rating, and consequently license herself to be “bad” by increasing her driving.

Another research project addresses consumer behavior and risk perception. Policies that incentivize consumers to buy energy-efficient cars effectively increase the share of small and light-weight cars on the road. Small and light-weight cars also increase hazard in case of an accident. But if drivers of small and light cars feel that their car is less safe, they might adjust their driving behavior accordingly, thereby offsetting the potential hazard.

RELEVANT PUBLICATIONS
Dr. Ofir Rubin focuses his research on economic modeling of energy markets, management of natural resources, and the economics and environmental aspects of renewable energy. In the realm of transportation, he investigates the performance of policies designed to promote energy efficiency as well as environmental and political objectives. Specific topics of interest include green taxation, alternative fuels in transportation and the conjunction of policy regulation with firms’ strategic behavior. His current project, funded by the Israeli Science Foundation, focuses on the impact of consumers’ response to policy regulation in terms of type of car purchased, fuel usage and implications for drivers’ risk perception and road safety.

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**Expertise**
Energy & environmental policy, modeling energy markets, energy efficiency in transportation

**RELEVANT PUBLICATIONS**

**DESCRIPTION**
Dr. Ofir Rubin focuses his research on economic modeling of energy markets, management of natural resources, and the economics and environmental aspects of renewable energy. In the realm of transportation, he investigates the performance of policies designed to promote energy efficiency as well as environmental and political objectives. Specific topics of interest include green taxation, alternative fuels in transportation and the conjunction of policy regulation with firms’ strategic behavior. His current project, funded by the Israeli Science Foundation, focuses on the impact of consumers’ response to policy regulation in terms of type of car purchased, fuel usage and implications for drivers’ risk perception and road safety.
Low-cost high-resolution infrared detector for autonomous car sensors

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Experteise
Low-cost infrared imaging sensors

OBJECTIVE
Autonomous car capabilities are very much dependent on the quality of its sensors and their performance. A very cost-effective focal plane array that can serve as an imaging sensor at the wavelength around 1550nm (SWIR—short wavelength infrared) could be the ultimate solution. Cameras based on such sensors will not be affected by sun glints and will be able to see through fog and dust. With such low cost devices, 4 to 6 cameras can be installed around the car for maximal situation awareness.

DESCRIPTION
We propose a novel device that is based on nanotechnology and solid state technology. This device, which is half a micrometer in thickness, converts the SWIR (1550nm central wavelength) image projected on one side of the layer into same visible image that is emitted from the other side of the layer. At present the photon to photon conversion efficiency is about 10%. When attached to any silicon CMOS or CCD visible detector, this layer converts it to an infrared detector. All non-uniformity correction is done simultaneously on the layer with the silicon detector that is attached to it. The overall cost of such a combined device can be as low as a few dollars. Therefore, several cameras can be installed on each autonomous car.

APPLICATIONS & PRODUCTS
Many applications are possible once one can make such an infrared sensor at a low price. The main application is in the field of autonomous vehicle sensors that are resistant to sun glints and can penetrate through fog and dust.

Additional applications are the second rear camera in advanced smart phones, where all the mechanical and electrical interfaces are the same for both cameras; defense and paramilitary applications (such as fire fighters), where such a device can be attached to the camera of augmented reality (AR) glasses, converting them into combined night vision glasses and AR glasses; and disposable swallowed devices, such as PillCam, where onverting the camera in to a SWIR camera can very much enhance pathologies-detection capability and at much earlier stages.

RELEVANT PUBLICATIONS
• G. Sarusi & Ibrahim Abdulhalim (2014). SWIR to Visible Upconversion Optical System. PCT 32594/US/14 (National Phase)
Aspects of connected vehicle networks

Prof. Michael Segal
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Expertise
Connected cars, inter- and intra-vehicle communications security

OBJECTIVE
I’m interested in designing efficient and secure communication mechanisms between vehicles themselves (V2V), between vehicles and the infrastructure (V2I), between vehicles and the cloud. The following are also of particular interest: distributed management of the swarm of autonomous cars; traffic management; security and privacy aspects in swarms; and location identification in autonomous swarms.

DESCRIPTION
A connected vehicle network is designed to provide a secure and private method for drivers to use the roads in a certain area most efficiently. Cars may connect to access points (Wi-Fi, 3G, LTE) through a central authority like a cloud, roadside units (RSUs) or communicate directly. Each kind of communication leads to different scenarios that require attention. For example, the cloud monitors and analyzes the car’s movements and other functions in order to provide certain services to the driver, like driving instructions. The legitimate questions here are how to keep the privacy of a driver’s information? Or alternately, if cars communicate directly, a malicious group of cars may try to gain leadership of the entire network in order to control all traffic and produce undesirable misbehavior. We are trying to resolve all such scenarios.

APPLICATIONS & PRODUCTS
We are usually interested in designing efficient algorithms that are validated by mathematical theory and extensive sets of simulation, producing both academic papers and patents.

RELEVANT PUBLICATIONS
OBJECTIVE
We are interested in the problem called "Multi-agent path finding" (MAPF). The input to the problem is a graph or an environment and a number of agents, each with its start and goal locations. The task is to find collision free paths for multiple agents from their start location to their goal location. This is a central problem in the artificial intelligence community and it has many possible applications in the area of traffic and transportation.

DESCRIPTION
Solving MAPF problems efficiently is topical due to the increasing importance of multi-robot systems in many applications, such as automated warehousing and automated airplane towing. Finding optimal or bounded-suboptimal MAPF plans is NP-hard for many versions of the MAPF problem and this makes the problem extremely challenging, especially when the number of agents is large. Our previous and current research focused on efficiently finding optimal or bounded suboptimal solutions to this problem. Many of the common algorithms for this problem have been developed in our lab. Currently, our research has shifted to focus on more real-world scenarios and adopting the various pure scientific algorithms to such real-world settings. Settings include (1) Continuous (non-discrete) environments, (2) Non-uniformly sized agents, (3) Interchangeable agents/robots, and (5) 3D environments and (5) Agents that appear and disappear during the problem solving.

APPLICATIONS & PRODUCTS
Many real-world problems have a strong component of MAPF. Automatic traffic control in junctions, or in general, have a strong MAPF component, as we want to lead the cars to their destinations as efficiently as possible without colliding with other cars. Similarly, robot warehouses and traffic control are other real-world applications of MAPF.

RELEVANT PUBLICATIONS
**OBJECTIVE**

Advance fundamental and applicative cutting-edge research in wireless communication, optical wireless communication, quantum key distribution, optical navigation, Li-Fi, visible light communication for Intelligent transport systems and smart city application.

Intelligent transport systems have become the chief technology for traffic management, monitoring and control, and increasing road safety. Radio frequency and optical wireless communication technologies have been proposed as a means for establishing communication between vehicular and road infrastructure, such as traffic lights, billboards and road infrastructures, and for providing inter-vehicular communication. These technologies provide one-way or two-way short-range to medium-range wireless communication links that are specifically designed for the automotive sphere. In addition, authentication between network elements such as vehicles, road infrastructure, and information systems has become extremely important in preventing hacking.

**APPLICATIONS & PRODUCTS**

Communication, navigation, and authentication for the next generation of transportation systems and autonomous cars.
OBJECTIVE
Support users via design.

DESCRIPTION
Human-machine systems consist of an arrangement of people and machines (or physical components) interacting within an environment in order to achieve a set of system goals. As such systems become more complex, smart and autonomous, the challenge of designing the interaction increases and more emphasis should be placed on agents’ mutual understanding and communication.

The shift from technology exploitation to technology for all users is challenging and requires user/use-centered design approaches. In my research, I explore how design can be influenced by user needs and characteristics, with the goal to improve acceptance and use and avoid misuse of complex systems.

APPLICATIONS & PRODUCTS
Vehicles and HMI, trucks and fleets, pedestrians and road traffic systems, drones and unmanned aerial systems, unmanned systems and autonomous vehicles.

RELEVANT PUBLICATIONS

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Expertise
Human factors engineering, human–machine interaction, Human autonomy teaming, Human–robot interaction, Decision support systems, User-centered design
ABOUT BGN TECHNOLOGIES LTD.

BGN Technologies is the technology transfer company of Ben-Gurion University of the Negev (BGU). BGN Technologies brings technological innovations from the lab to the market and fosters research collaborations and entrepreneurship among researchers and students. To date, BGN Technologies has established over 100 startup companies in the fields of Biotech, Hi-tech and Cleantech and initiated leading technology hubs, incubators and accelerators. During the past decade, BGN Technologies focused on creating long-term partnerships with multinationals such as Deutsche Telekom, Dell-EMC, Lockheed Martin and PayPal, securing value and growth for BGU and the Negev region.

http://in.bgu.ac.il/en/BGN

ABOUT BEN-GURION UNIVERSITY OF THE NEGEV

Ben-Gurion University of the Negev is the fastest growing research university in Israel. With 20,000 students, 4,000 staff and faculty members, and three campuses in Beer-Sheva, Sede Boqer and Eilat, BGU is an agent of change, fulfilling the vision of David Ben-Gurion, Israel's first prime minister, who envisaged the future of Israel emerging from the Negev. The University is at the heart of Beer-Sheva’s transformation into the country’s cyber capital, where leading multinational corporations leverage BGU’s expertise to generate innovative R&D.

As it counts up to its fiftieth anniversary, BGU's mission continues to be effecting change, locally, regionally and internationally. With faculties in Engineering, Health Sciences, Natural Sciences, Humanities and Social Sciences, Business and Management, and Desert Studies, BGU is a university with a conscience, active both on the frontiers of science and in the community. Over a third of our students participate in one of the world’s most developed community action programs. BGU is a recognized national and global leader in multiple fields, actively encouraging multi-disciplinary collaborations with government and industry, and nurturing entrepreneurship and innovation in all its forms.

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