机器人与智能制造：机遇和挑战

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• 背景介绍
• 火箭技术：创新驱动产学研
• 爬壁机器人：从研发到应用
• 智能机器人：挑战
• 结语
New Zealand is located in the South Pacific between the Pacific Ocean and the Tasman Sea, between latitude 35 and 45 degrees south.

2,000 kilometres southeast of Australia across the Tasman Sea. About 3 hours flight to Sydney.
新西兰 – 陆地和海域

Total Area: 268,680 km² (244,820 km² -- United Kingdom)

330 islands with 18,218 kilometres of coastline

The sixth largest marine environment in the world, at more than 4.4 million square kilometres.

Extended continental shelf (1.7 million square km, awarded the right in 2008)
Small population

NZ Population: 4,374,632
as at Tues, 17 Aug 2010 at 09:42:57 pm

GDP Per Capita 2009: NZ$46,683, or about US$32,000

Many animals

3.5 million cows. NZ produces some 15% of world dairy products but controls over 42% of world dairy exports.

Plants everywhere

Agriculture, horticulture and forestry account for more than half of New Zealand's exports.
New Zealand: Home of Lord of Rings
基督城（克里斯彻奇）- 花园城市

- Population: ~400,000. The second largest city in New Zealand.
- Christchurch / Southern NZ - the wine capital of New Zealand, member of Great Wine Capitals Global Network.
- “More English than England”.

亚芳河

Hagley Park
陈小奇的10公里跑道
“I think every person..... dreams of finding some enchanted place of beautiful mountains and breathtaking coastlines, clear lakes and amazing wildlife. Most people give up on it because they never get to New Zealand”

Mr. Bill Clinton – Former US President
Gala Dinner, Christchurch, New Zealand, 2000
Bio-mechatronics
- Assistive devices
- Bio-micromanipulation

Mobile Robotics
- Unmanned aerial vehicle
- Underwater robot
- Wall-climb robot
- Land based robot

Instrumentation and Automation
- Manufacturing automation
- Additive manufacturing
- Tissue engineering

Cell injection
FDM Validation with On-Board Instruments

- Equipment used
  - 2.4 meter wing-span gas powered RC plane
  - GPS base station
  - Inertia navigation system
  - Servo pulse acquisition device
  - Wind speed sensor
  - Data logger
  - Wind tunnel

Canterbury UUV - Biosecurity

For shallow waters, up to 20m depth


Video: QEII Pool Test
林业机器人

Vertical Reach

Horizontal Reach
仿生蛇形机器人

**Innovation**

- Modular design, scalable
- Robust and resilient (fault tolerant)
- Gait parameterisation
- Agile biomimetic locomotion:
  - Lateral undulation
  - Linear Progression
  - Lateral Rolling
  - Turning
  - Side Winding

**Potential Applications**

- Search and Rescue
- Structure & bridge inspection
- Understructure inspection
IRMAC - Integrated ROS based Robotic Modelling And Control
UC 火箭研发

Propulsion System Design and Build

Airframe Design and Build

Avionics Design and Build

Integration of Propulsion, Airframe, Avionics and Actuators

Wind Tunnel Testing

Final launch with extensive media coverage
Propulsion

- Stress analysis
- Isentropic nozzle flow theory
- Propellant burn properties
- Motor customisation
- Performance testing

Expansion_ratio := \left(\frac{k + 1}{2}\right)^{\frac{1}{k - 1}} \cdot \left(\frac{p_{\text{exit}}}{p_{\text{chamber}}}\right)^{\frac{1}{k}} \cdot \frac{k + 1}{k - 1} \cdot \left[1 - \left(\frac{p_{\text{exit}}}{p_{\text{chamber}}}\right)^{\frac{k - 1}{k}}\right]^{\frac{1}{2}}
Airframe

- Body
- Nosecone
- Compartments
- Bulk heads/mounts
- Actuator linkage
- Fins
- Parachutes/deployment
- Onboard Camera
- Assembly

Mass: 5kg
Length Overall: 1.3m
Rocket Roll Dynamics and Disturbance Minimal Modelling and System Identification

Wind Tunnel Dynamic Response

MATLAB System Identification

What can go wrong

Wind Tunnel Controller Validation

Implementation
Avionics Hardware

- Main Control Board
  - Main micro (ARM7-based)
  - Barometer
- Inertial Measurement Unit
  - Gyros, Accelerometers
  - 16 bit ADC (8 channels)
- Comms. and Data Logging Board
  - XBee Modules (Zigbee Protocol)
  - Flash Memory
- Power Supply Board
  - Switching Power Supply
- Servo Controller Board
  - 2 x ATMega168 micros
  - I2C Bus
  - Servo Outputs

Video: Vertical Wind Tunnel Test of Roll Control
Software & Integration

Software

- On-board avionics software
- Ground station software
- Communication between on-board and ground station
- Control algorithm and software

System integration

- Control Avionics and Communications
- Propulsion and Associated Systems
- Recovery Systems
- Airframe
首次试射 (2010)

Video: final launch
Rocket Lab in deal with US aerospace firm (staff.co.nz 01/12/2010)

Rocket Lab was founded by Mr Peter Beck and Mark Rocket.

Launched Atea-1, a 6-metre long, 60 kilogram rocket into space in November 2009, believed to be the first private rocket launched in the Southern Hemisphere.

It has since won contracts from the US Government, the Australian defence force and major defence contractor Lockheed Martin, although the latest deal was the largest to date.

Rocket Lab's new partner, L2 Aerospace, is headed by retired four-star General Lance Lord, the former head of the US Air Force Space Command, where he was in charge of 47,000 military personnel and staff.
Robotic research at the University of Canterbury has climbed new heights with the development of a wall-climbing robot.

The robot has been developed by a team of researchers led by Associate Professor XiaoQi Chen in the University’s Mechanical Engineering department.

**A journey of wall climb at UC**

- 2006: Initiated the research
- 2007: Non-contact wall climbing prototype
- 2010: Invert Robotics Limited was formed.
- 2012: Completed its first job inspecting a milk powder dryer for Westland Milk in Hokitika
- 2012: Received MSI Best Start-up Award
State of Art Wall Climbing Robots

- SUCTION PADS
- ELECTROSTATIC ADHEASION
- GECKO FEET
- VORTEX ADHEASION
- THRUST
### Non-Contact Adhesion Wall Climbing Robot - Motivation

<table>
<thead>
<tr>
<th>Adhesion</th>
<th>Surface Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>Smooth, Non-permeable</td>
</tr>
<tr>
<td>Magnetic</td>
<td>Ferromagnetic</td>
</tr>
<tr>
<td>Microfibre</td>
<td>Clean</td>
</tr>
</tbody>
</table>

**Desired:** adhesion effect independent of materials and surface conditions

**Challenge:** Efficient adhesion device insensitive to surface conditions
Total weight: 234g
Max attraction force (at 5 bar): 12N

The robot is able to transverse the gaps on the wall

High manoeuvrability in every direction, and on different surfaces.

Additional 500g weight is lifted.

Video
Untethered Wall Climbing Robot
无拴线爬壁机器人

Hidden microbes in weld cracks can taint millions of litres of milk!

6 person team, 6 hour inspection process with safety concern

1 operator, 0.5 hour inspection, operating outside tank
Innovation

- Active primed suction
- Untethered
- Onboard sensing and control
- Force feedback control
- Energy efficient, run continuous hours
Applied Load vs. Pad Diameter

Line should pass through zero, Constant $B$ is proportional to gripper size $y = 0.945x - 41.537$

- Natural Rubber 3.8
- Natural Rubber 4.8
- Nitrile 3
- Insertion reinforced 3
- Insertion reinforced 4.8
- Insertion 2x reinforced 7.5

Pad Diameter [mm]
Robot inspection in action

Video: untethered
Explosion of Robotics Development

- Unmanned Aerial Vehicle, flying robots
- Unmanned Underwater Robots
- Climbing and walking robots, rescue robots
- Bio-inspired robots: humanoid, pets, cockroach, gecko, fish
- Agricultural robots: plough, sowing, harvesting
- Medical & assistive robots
Into Our Homes
- Members of family?

- Free us from home chores: vacuuming floor, mowing lawn.
- Robot butler.
- Robot assistant for elderly, handicapped.
- Patrolling, security.
The Reality...
Natural disaster ... where rapid recovery response is needed

The magnitude 6.3 earthquake struck Christchurch at 12:51 pm on Tuesday, 22 February 2011, claiming 185 lives.

Wenchuan earthquake (汶川大地震), magnitude 8.0, occurred on Monday, May 12, 2008, killing ~68,000 people.

Fukushima I Nuclear Power Plant (福島第一原子力発電所事災) disaster, nuclear meltdowns, and releases of radioactive materials, following the Tōhoku earthquake and tsunami on 11 March 2011.

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## Comparison of lifting capacity between robots and human

<table>
<thead>
<tr>
<th></th>
<th>Self weight (Kg)</th>
<th>Lifting capacity (Kg)</th>
<th>Lifting-to-weight ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB IRB 2000</td>
<td>350</td>
<td>10</td>
<td>~0.03</td>
</tr>
<tr>
<td>Honda Asimo</td>
<td>52</td>
<td>1 (for two hands)</td>
<td>~0.02</td>
</tr>
<tr>
<td>2008 Olympic Women 53 Kg Weightlifting Gold</td>
<td>53</td>
<td>126 (clean &amp; jerk)</td>
<td>~2.4</td>
</tr>
<tr>
<td>A person having similar weight to Asimo</td>
<td>52</td>
<td>~20</td>
<td>~0.4</td>
</tr>
</tbody>
</table>
Inventing it is half the job

“Inspiring” was the word to describe last week’s unveiling of the Rex Bionics robotic exoskeleton in Auckland. Not only for Rex’s potential to transform the lives of paraplegics, but as yet another example of Kiwi ingenuity.

You could be forgiven from reading media reports that all the company has to do is start cranking the robots out of the factory and money will come pouring in.

The people behind the company, including venture capital company No 8 Ventures, will understand that inventing Rex is only half the job. Working out how to sell enough of them at a profitable price is the tough challenge remaining.

After seven years of development and $10 million in investment, Rex isn’t the first robotic exoskeleton cab off the rank. General Electric made one for the US Army in the 1960s, and giant companies like Lockheed, Raytheon and even Honda have laid a go. Israeli company Argo Technologies has developed an exoskeleton called ReWalk which is undergoing clinical trials and seeking FDA approval in the US.

What stands out about the Rex is its typically Kiwi twist, focused not on being the absolutely bleeding edge but being a practical tool. Much like another No 8 backed initiative, the Martin Jetpack, the Rex is an attempt at a usable version of once-futuristic technology.

Owen Scott

Marketing

said, “At US$50,000, Rex is by no means inexpensive, but it does offer wheelchair users a practical and (almost) readily available means of getting out of their chairs.”

Nor being first doesn’t matter either – it is who can provide the best complete solution to the market need that counts. It is not the absolute highest-tech product, or the one with all of the features, but the best answer to the customer’s particular problem that wins.

The Segway scooter was launched nine years ago, but has yet to record the number of sales originally forecast for it in the first nine months, according to an article in the Economist. It was, and is, cutting edge technology, but it simply didn’t fit the lives of the customers it was aimed at – people bustling the busy streets of large cities. As the Economist concluded, “there is a big difference between coming up with an idea and making it happen”.

What I like about the Rex is that they have focused on a specific group of customers – paraplegics – and describe their product as a complement to a wheelchair (at least at this stage in the lifecycle of the product).

They haven’t pitched it as all things to all people, an ‘ironman’ come to life.

So congratulations to Rex’s founders for their courage and vision. It is just what the government was seeking to foster with the research science and technology strategy announced in the recent budget.

This was reinforced by the attendance of Prime Minister John Key at Rex’s launch.

The government’s initiatives are positive for the country’s innovation-based companies, but are an incomplete approach, based on the assumptions that businesses already have commercialisation capability for turning new research ideas into export dollars.

Despite some obvious success stories, we don’t have a great record at finding people to sell inventions at a profit. That New Zealand hasn’t yet built a lot of large scale technology-based businesses, with a few outstanding exceptions, is evidence of this commercial weakness.

Taking a product to market is as much a process as the scientific method. Success commercialising a concept is highly dependent on a firm’s ability to focus, intently understand their market and build an effective capability to engage on the customers’ terms.

Owen Scott is from marketing firm Concentrate.
concentrate.co.nz
结语

• 机器人在许多领域里已成功地代替人工，有效地完成重复和可预测的任务。

• 智能制造和作业需要高度自主的机器人系统，并能做到机器-机器协调和人机协调。

• 现今的机器人技术还有很多的不足，如承载与自重比率，运动灵巧性，决策等

• 机器人更广泛的应用有待于新的技术突破
  - 新的驱动机构
  - 叠代学习功能
  - 视觉识别
  - 人机协调与交互
30年后的机器人能否像现在的个人电脑一样影响我们的生活和工作？