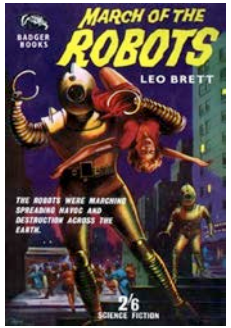
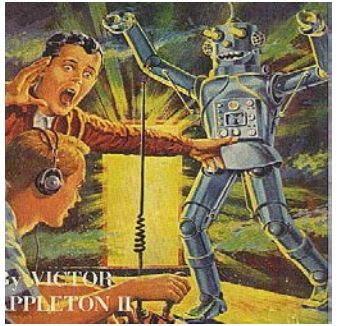
The Future of Autonomous Robots





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Expert Group

- AAS Expert Group, sponsored by DST

First	Last	Institution	Role	Expertise
Peter	Corke	QUT		Computer vision, manipulation
Gamini	Dissanayake	UTS		Manipulation, navigation, human-robot systems
Hugh	Durrant-Whyte	University of Sydney	Chair	Data fusion, navigation, perception
Rob	Mahoney	ANU		Vision, control, UAVs
Saeid	Nahavandi	Deakin		Swarm robotics, defence applications
Denny	Oetomo	University of Melbourne		Legged Robots, biomedical robotics
Ian	Reid	University of Adelaide		Computer vision
Claude	Sammut	UNSW		Machine learning, AI, logic, robocup
Kate	Smith-Miles	Monash		Computation, algorithms, optimisation
Robert	Sparrow	Monash		Robot ethics
Srini	Srinivasan	University of Queensland	Co-Chair	Biologically-inspired robotics
Salah	Sukkarieh	University of Sydney		Field robotics, navigation, planning
Toby	Walsh	UNSW		Artificial intelligence, impact of robotics
Mary-Anne	Williams	UTS		Human-robot interaction, artificial intelligence

Australia has World-Class Robotics Research

Top Level Objectives of Study

1. What is the current state of the art in autonomous robotics?
2. What is the vision for autonomous robotics in 10-20 years?
3. How realistic is this vision?
4. What technologies will need to be developed to realise this vision?

Report due 1st half 2017

Report Structure – Addressing Objectives

- **Part I** – The Vision and Challenge:
  - Top-level ***vision*** of future robotics – the positives and negatives
  - Key technology ***challenges*** - what is needed to realise vision
- **Part II** – The Vision
  - Articulated through six current and future application domains
  - For each – Vision, Current State, Future Challenges
- **Part III** – The Challenge
  - Six main technology and societal challenges for future robotics
  - For each – current, achievable technology, hard problems
- **Part IV** – Skills, Training and Business
- **Part V** – Conclusions and Recommendations

Part I: The Vision and the Challenge

- An introduction providing:
  - the vision of autonomous robots
  - where we are now
  - key conceptual and technical challenges
  - the Australian context
  - summary of the report.

Part I: The Vision and the Challenge

- Key Points:
  - Machines that serve humanity:
    - more productive, safer, healthier human lives
  - Approaching a tipping point:
    - Recent advances have brought the vision closer than ever
    - Increasingly uncertain and unpredictable environments
    - Opportunities versus fears
  - In many sectors robotics will be an everyday reality in 20 years
  - However, Some areas are over-hyped:
    - Full human-engaged autonomy not likely in 20 year scope
    - In some sectors, the right questions have not yet been asked
  - Australia has a unique and major role to play in robotics

Part II: The Vision

- A focus on future applications enables “envisionment”
- A focus on applications also drives questions around key technical and research challenges:
  - What is the maturity of current robotics technology?
  - What is a realistic future vision for what robotics technology could do in the next twenty years?
  - How will the technology progress to make this achievable?

Part II: The Vision - Applications

- Six application areas:
  1. **Social robotics** – domestic robots
  2. **Health robotics** – clinical health care, nursing and physical patient management.
  3. **Transport** – air, ground and sea
  4. **Worksites** – mining, resources, construction, agriculture
  5. **Environment** – terrestrial, marine and planetary stewardship
  6. **Defence** – surveillance, training, decision support and combat

Part III: The Challenge

- Technology and societal challenges for future autonomous robots
- Draws together threads from the six envisaged future applications
- Focus on six critical areas:
  1. **Human interaction**
  2. **Action**
  3. **Perception**
  4. **Cognition**
  5. **Enabling technologies**
  6. **Robots and society**

"The intelligent connection of perception to action", JM Brady

Part III: 1. Human Interaction

- Robot-human interaction is key to many envisaged applications
- Interaction is still very primitive in most cases
- Technical challenges:
  - Modelling human behaviour
  - Awareness and intention
  - How robots affect people
  - How people interact with robots
  - Situational awareness
  - Communication: robot to robot / human to robot / robot to human
  - Adaptation and learning in real time
  - Forming relationships

Part III: 2. Action

- Action and actuation with human or animal-like dexterity is the goal
- Any areas, including running, manipulation, and bird or insect-like flight are beyond current abilities – challenges include:
  - Adaptation and self-repair
  - “Actuation at the edge”
  - Muscle-like actuation
  - Softrobotics
  - Swarm behaviour

Part III: 3. Perception

- Perception – sensing, interpretation and environment modelling is arguably still the most challenging and complex problem in robotics
- Multiple challenges:
  - Sensors – vision, 3D vision, lasers, hyperspectral, haptics, etc
  - Sensor fusion – multiple sensors, multiple platforms
  - Persistent perception
  - Modelling and situational understanding
  - Mapping, navigation and SLAM
  - More …
- Major breakthroughs in perception have occured in the last 5 years

Part III: 4. Cognition

- Cognition: “When we don’t know how to solve the problem, it is called AI. When we know how to solve it, it is called an algorithm”.
- Challenges are around modelling and learning:
  - Machine learning
  - Reinforcement learning
  - Logic methods
  - Neural networks
  - Transfer learning (with humans)
  - Copying the human brain

The link between perception and cognition not well understood

Part III: 5. Enabling Technologies

- Robotics relies critically on many other technologies
- Robotics typically advances when other technologies advance
- Examples include:
  - Sensor types – cameras, haptics, lasers
  - Materials and actuation technology
  - Power sources
  - Machine learning

Non-technical challenges

- Key non-technical issues identified:
  - How to build the right robotics business environment in Australia
  - How to develop the skills and practical deployment capabilities
  - What should we do about future of jobs and employment
  - To what degree should robots be controlled at this stage
  - Trust, regulation and compliance recur in all applications
  - Societal and ethical issues

Conclusions

- A tipping point has been reached in many applications
  - Disruption already happening in sectors where the environment can be somewhat controlled (e.g. some worksites)
  - This trend will continue, increasing the sectors in which autonomous robots have penetration
  - Full autonomy in transport probably still 10-15 years away
  - Generic helpers 20 years away
- Perception (and to an extent, cognition) have been revolutionized by machine learning (data is key)
  - Algorithmic technologies—perception, cognition, decision making—are often the most complex and challenging, and most often the limiting factors in what can be achieved
  - These remain the most significant barriers to full autonomy
  - As these improve, so too will penetration of autonomous robots into other areas
- But easily over-hyped
  - Many hoped applications are far beyond current understanding in building intelligent, perceptive and trustworthy machines.
  - The less structured and predictable the environment a robot has to deal with and work within, the less likely current technology can deliver a resilient solution.
  - Areas such as robotic surgery and autonomous highway driving are achievable precisely because they have relatively low levels of environment and process uncertainty