Accelerating the Future: Designing a Robust and Affordable Radiation Therapy Treatment System for Challenging Environments

Bristol Learning, Estimation and Control Team

Issues of Integration & Other Things

Dr GUIDO HERRMANN, FIET, SenMIEEE

From 1 July 2019 Chair in Robotics & Control at the University of Manchester

The University of Manchester

Professor Stuart Burgess,

Professor of Engineering Design

The Presentation

1. Research and Research Credentials
2. Examples of Design / Control in Robotics & Mechatronics
3. ? Road Map
4. Design Methods
5. Conclusions

Professor Stuart Burgess

- In 1993 awarded the UK Turners Gold
- worked at European Space Agency for 5 years mainly working on the ENVISAT (launched in 2002) earth observation satellite which is the largest civilian satellite in the world: lead designer of solar array deployment mechanism including inventing a new type of gearbox - the double action worm gear set (world patent)
- helped in the development and selection of chains and chainrings for the world-beating track bikes: Britain racked up a total of 11 medals in the Olympic velodrome 2016, with every member of the 10-strong track cycling team winning at least one

Guido Herrmann - Robotics & Mechatronics

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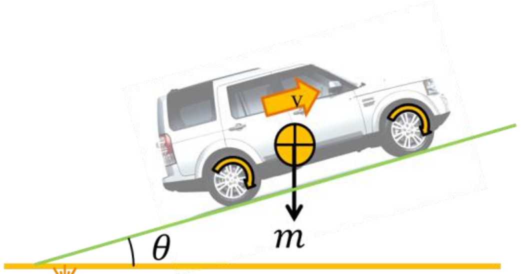
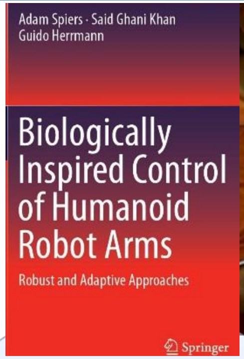
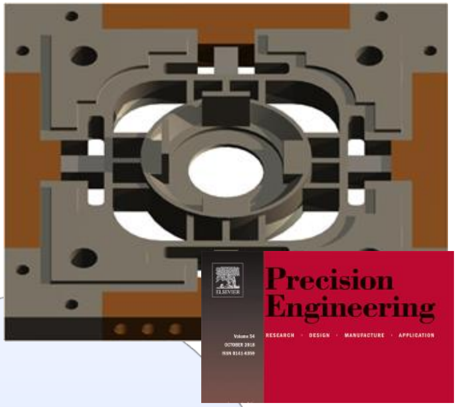


IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY





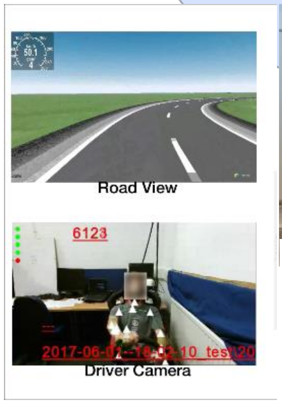
Automotive

Human Robot Interaction

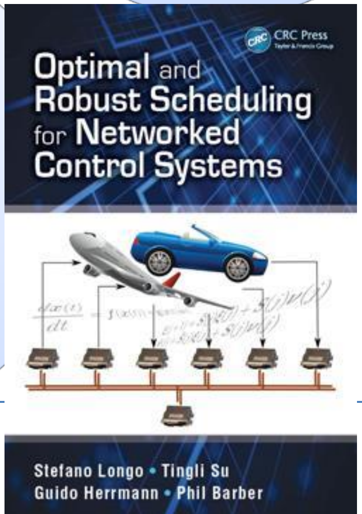
Robotic Control

Nano-Precision Technology

Networked Control



TAROS 2017 – Best Poster



IET 2011 Control PhD Award for Dr Stefano Longo

Guido Herrmann - Examples of Control in Robotics

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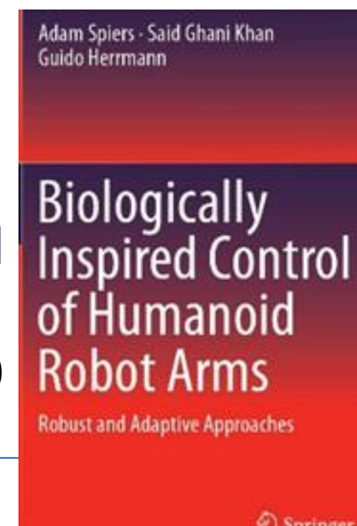
Khan, SG, Herrmann, G, Lenz, A, Al Grafi, M, Pipe, AG & Melhuish, CR 2014, 'Compliance Control and Human-Robot Interaction: Part II - Experimental Examples' International Journal of Humanoid Robotics.

S.G. Khan, G. Herrmann, A.G. Pipe & C.R. Melhuish, Adaptive Multi-dimensional Compliance Control of a Humanoid Robotic Arm with Anti-Windup Compensation, 2010 IROS, Taipei, 2010

Khan, SG, Herrmann, G, Pipe, AG, Melhuish, CR & Spiers, A 2010, 'Safe Adaptive Compliance Control of a Humanoid Robotic Arm with Anti-Windup Compensation and Posture Control' *International Journal of Social Robotics*,



Co-Investigator on £24m, e.g. UKAEA: UK Atomic Energy Authority

EP/R02572X/1 National Centre for Nuclear Robotics (NCNR)
EP/R026084/1 Robotics and Artificial Intelligence for Nuclear (RAIN)

De Silva, G., Burgess, S.C., Hatano, T., Khan, S.G., Zhang, K., Nguyen, T., Herrmann, G., Edwards, C. and Miles, M., 2017. Optimisation of a nano-positioning stage for a Transverse Dynamic Force Microscope. *Precision Engineering*, *50*, pp.183-197.

? Road to A Robust and Affordable LINAC

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2016-2019

- **LINAC:** High Level and Functional Systems Model

2020-2022

- **LINAC:** Functional Subsystems and Interface Analysis
- Involvement of local technologists, e.g. iThemba

2023-2025

- **LINAC:** Prototype and Safety Verification

2026-2029

- **LINAC:** Production Arrangement

CERN & STFC

ICEC

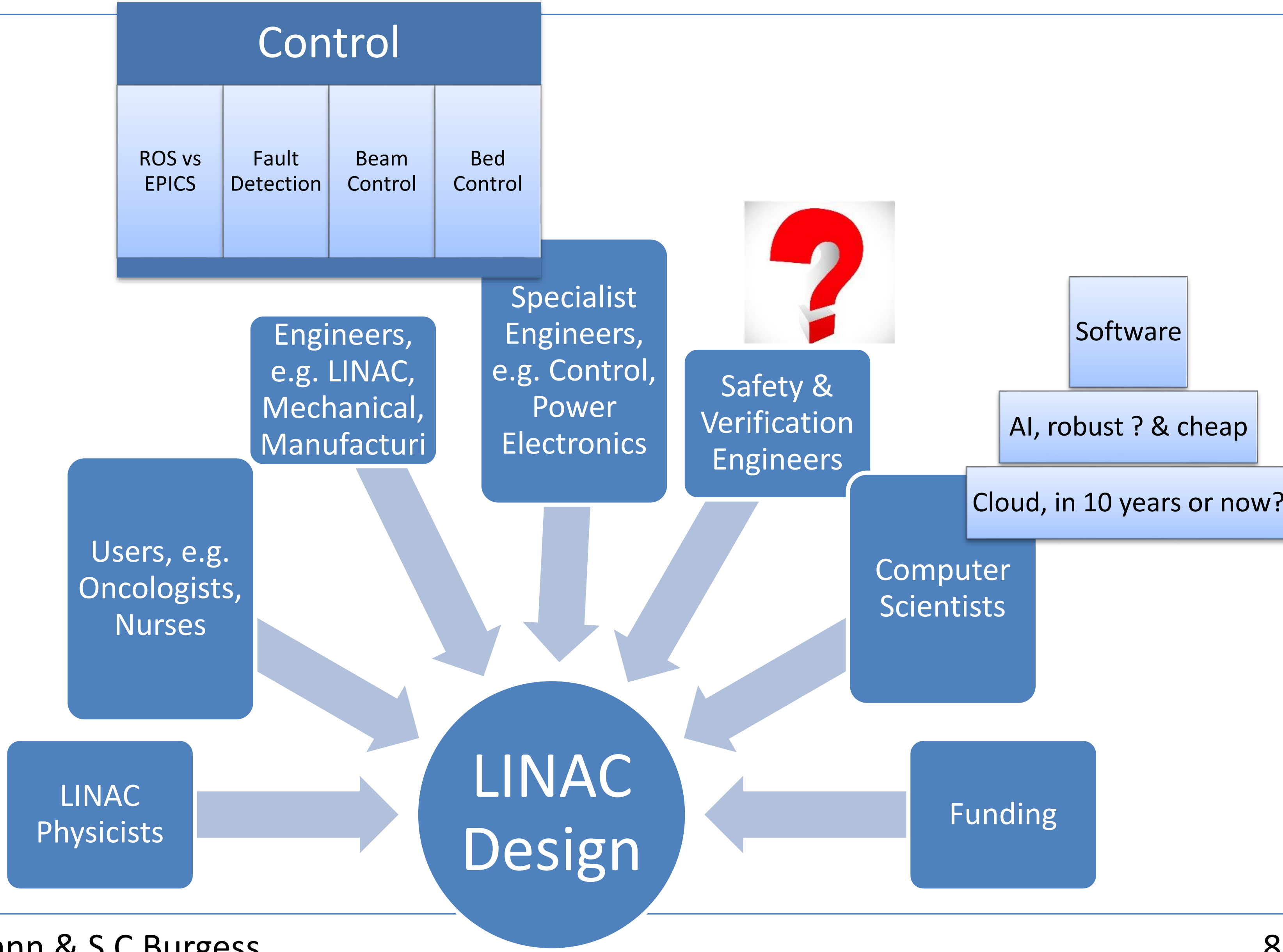
Training: Connection to Teaching Hospitals

Training: LINAC/Oncology Staff Training enabled by Teaching Hospitals

Training: Centers of Excellence hosted by Teaching Hospitals, seeds for new centers

Delivery of first LINAC to Centers of Excellence

? Road to A Robust and Affordable LINAC



Design methods

(1) High-level systems modelling

(2) Functional decomposition

(3) Structured questioning

(4) Cost modelling

(5) Interface analysis

(6) Conceptual design methods

(7) Prototyping

(1) High-level (soft) systems modelling

To identify the stake holders and the relationships between them (researchers, designers, users, regulators, purchasers, patients etc)

Purpose: to help clarify requirements, relationships and constraints

(2) Functional decomposition

For example morphological charts:

Matrix of sub-functions versus sub-solutions

Purpose: to understand the design and to clarify the design-drivers

Morphological chart for a sports car

Sub functions	Sub-solutions					
Body shape	micro	mini	coupe	hatch	estate	sedan
Engine	IC	Micro Hybrid	Mild hybrid	Full hybrid	Plug in hybrid	Electric
Gearbox	Manual 5g	Automatic	Auto CVT	Man + Auto	Manual 6g	
Drive	Front wheel	Rear wheel	4 wheel drive	2 or 4 wheel		
Suspension	McPherson	Double wishbone	Horizontal pushrod	Active		
Wheels	Steel	Alloy	Wide steel	Wide alum		
Tyres	Standard	Run flat	All terrain	Small section height		
Fuel	Deisel	Petrol	Electric	D + battery	P + battery	
Battery	Lead acid	Lithium				
Body material	Steel	Aluminium	CFRP			
Chassis	Body on frame	Unibody (monocoque)				
Bumpers	Steel	Aluminium	Plastic	CFRP		
Doors	4 door	4 door hatch	2 door	2 door hatch		

(3) Structured questioning

- Does the machine need to be so compact or light?
- Does the machine need to be so sophisticated?
- Does the machine need to be so accurate or fast?

Purpose: to systematically review the design to look for ways of relaxing or extending the specification as necessary

(4) Cost modelling

- Identify cost-drivers in the existing design
- Identify alternative cost scenarios

Purpose: to reduce costs

(5) Interface analysis

- Identify/review existing mechanical and electrical interfaces
- Create more/clearer interfaces to allow for modular design

Purpose: to create modular design to reduce costs

(6) Conceptual design methods

- Learn from relevant successful examples of cost reduction
- Brain-storming sessions using multi-disciplinary teams
- Backwards design – work backwards from an ideal design
- CAD modelling to explore options
- Inversion – investigate doing things the other way around (e.g. turn the body not the machine)

(7) Prototyping

- Prototyping of critical areas including hardware-in-the-loop (Breadboard model, engineering model, qualification model, etc)

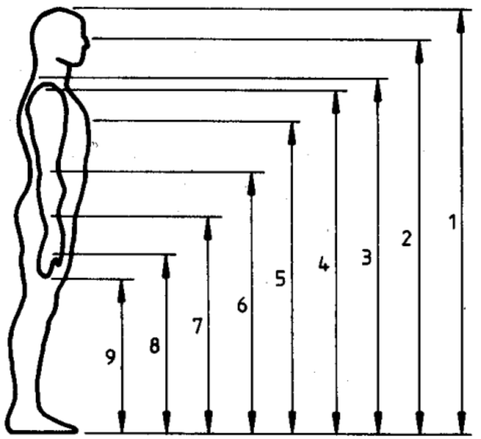
Purpose: speed up the design process

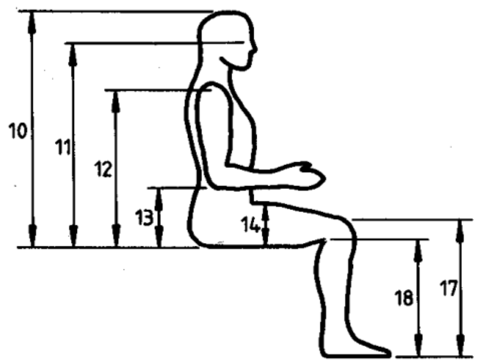
Reference

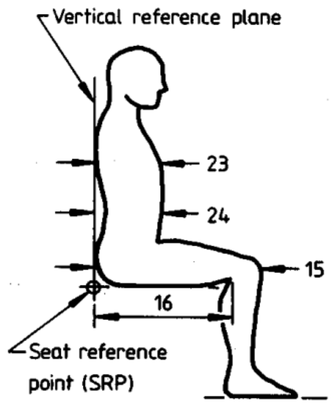
Burgess, SC, *A backwards design process for Mechanical Design*, Journal of Mechanical Design, ASME, Vol 134, 031002, pp 1-10, March 2012.

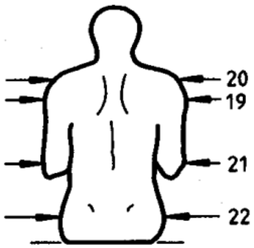
Anthropometric data (BS PP 7310)
Around 50 dimensions (per male and female)

Data based on “normal distribution”





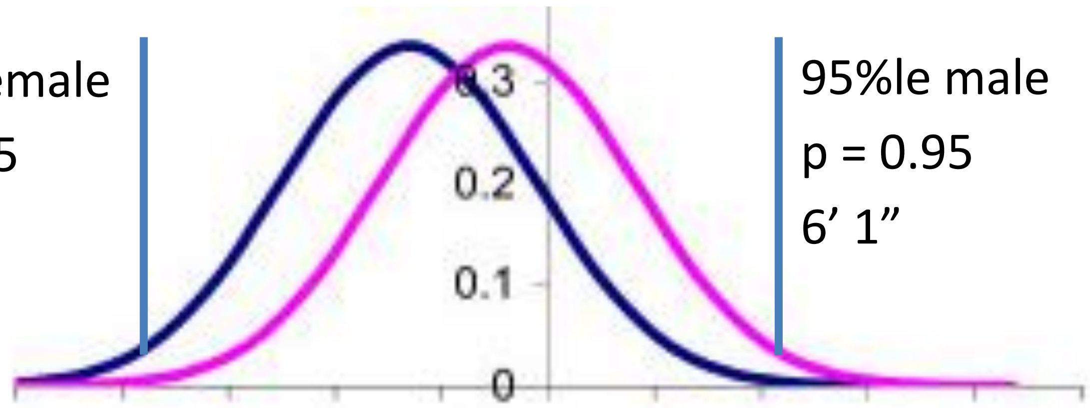




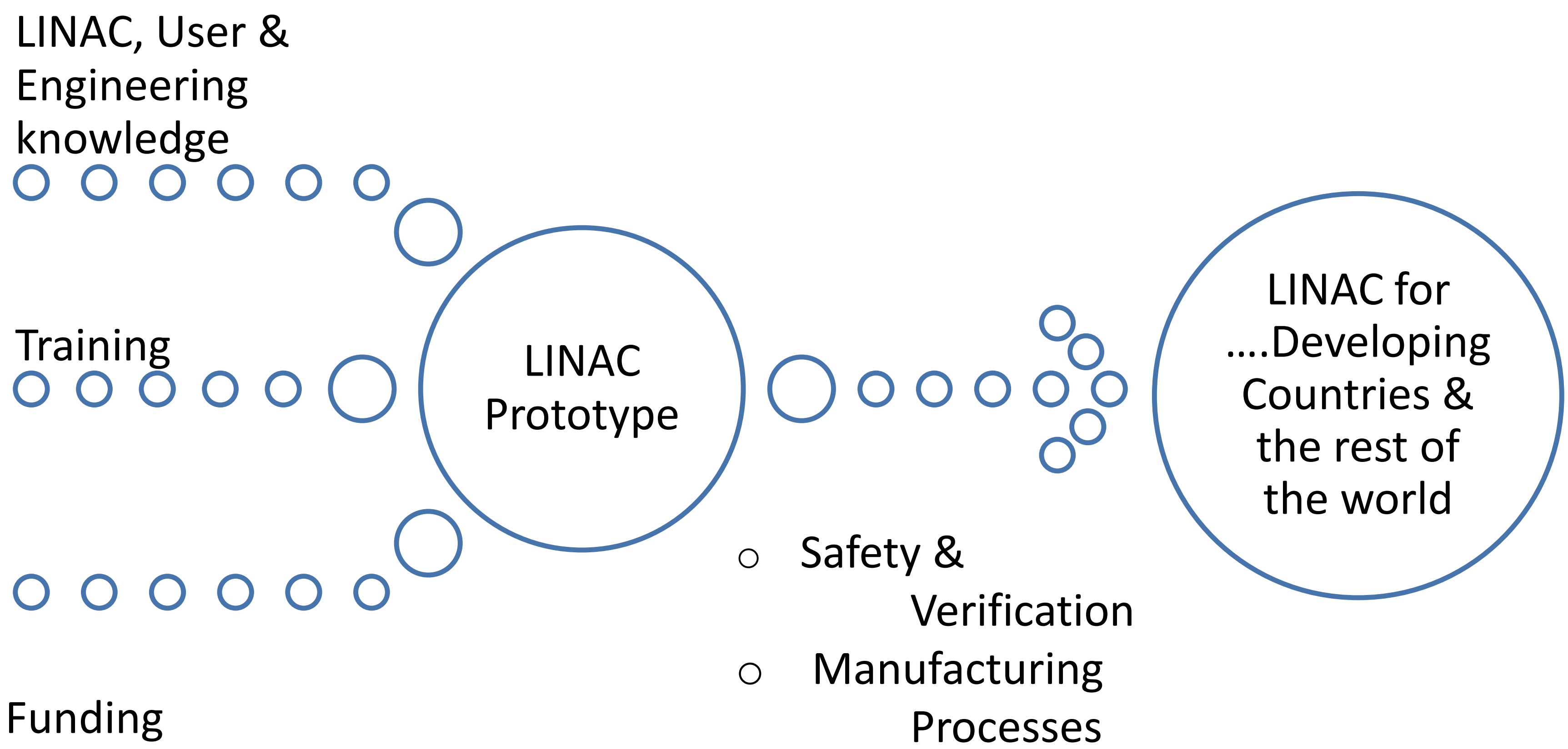
Anthropometric data (BS PP 7310)
Around 50 dimensions (per male and female)

Common guideline to design for 95%le male/ 5%le female

5%le female
p = 0.05
4’ 11”



95%le male
p = 0.95
6’ 1”


LINAC, User & Engineering knowledge
Training
Funding
LINAC Prototype
LINAC for ....Developing Countries & the rest of the world
○ Safety & Verification
○ Manufacturing Processes


Thank You


Thank You