The findings of studies into the safety of greyhound tracks and actions taken to improve safety

11 Dec 2018

GWIC
GREYHOUND WELFARE & INTEGRITY COMMISSION

UTS

Prof David Eager
School of Mechanical and Mechatronic Engineering
Faculty of Engineering and Information Technology

OUTLINE

- **Data analysis**
- **Greyhound’s dynamics measurement**
  - Kinematic analysis
  - Kinetic analysis
- **Track simulation**
- **Advanced 3D paw imprint reconstructiong**
- **Surface safety analysis**
- **Future work**

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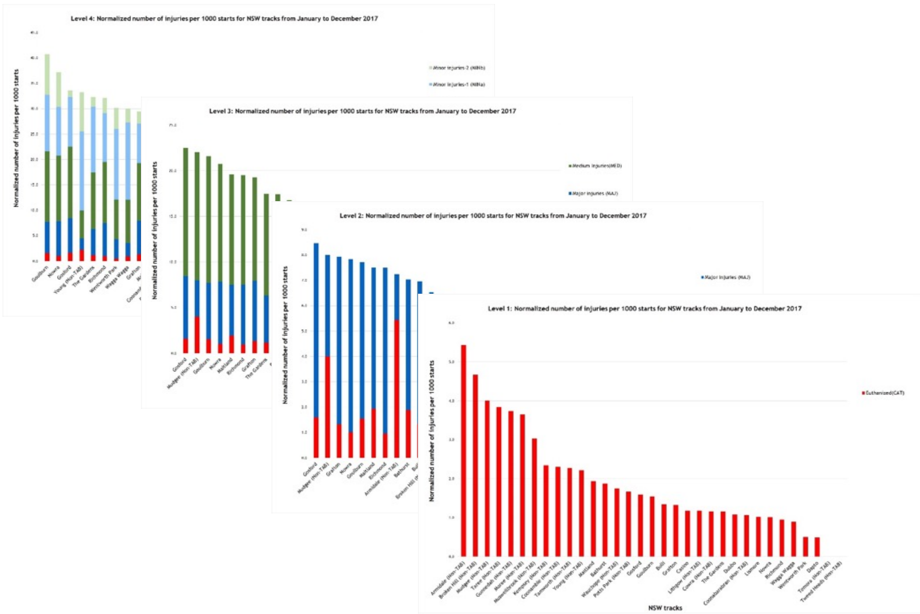
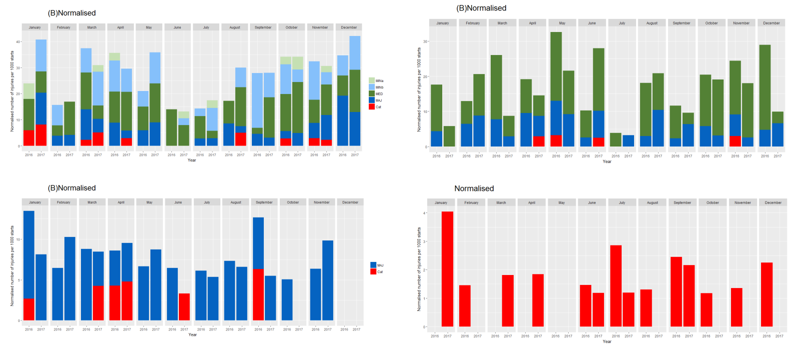
DATA ANALYSIS

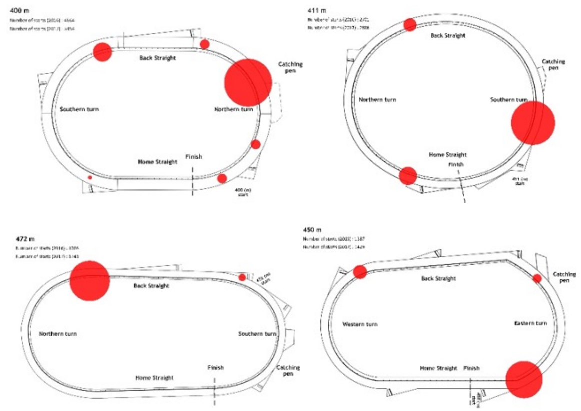
(1)



(2)



(3)



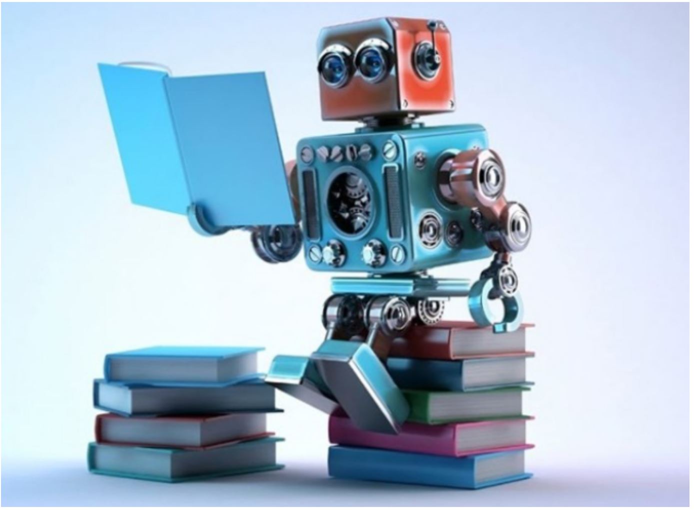
(1) Annual

(2) Monthly

(3) Location

DATA ANALYSIS

- Statistical tests
  - T-test
  - Chi-square test
  - ANOVA
  - Fisher’s exact test



- Pattern recognition using machine learning algorithms

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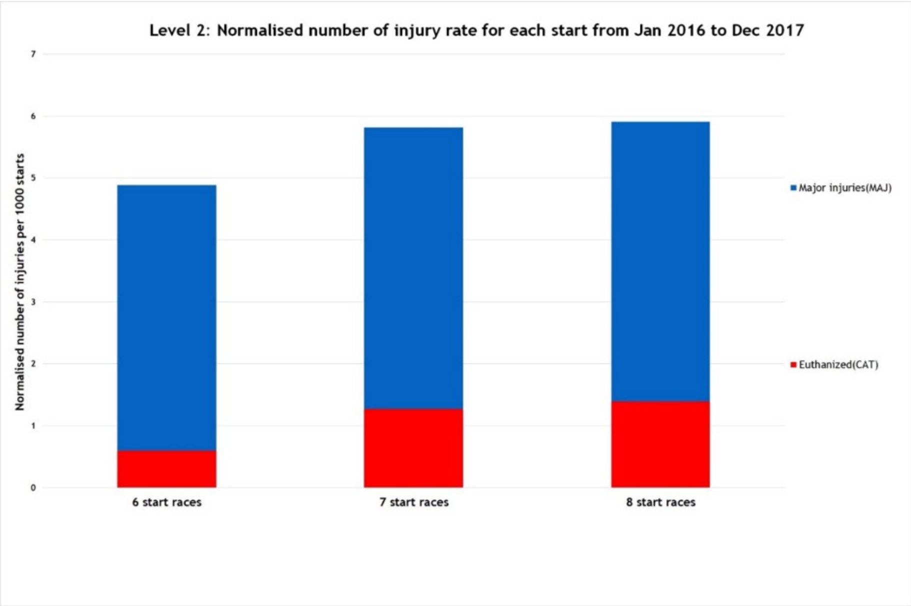
DATA ANALYSIS – 6 v 8 STARTS



	2016 Deceased	2016 Starts	2017 Deceased	2017 Starts	Normalised per 1000 starts (2017 & 2016)
6 Start races	3	4032	2	4356	0.6
7 Start races	23	15435	15	14483	1.3
8 Start races	103	70128	92	69952	1.4

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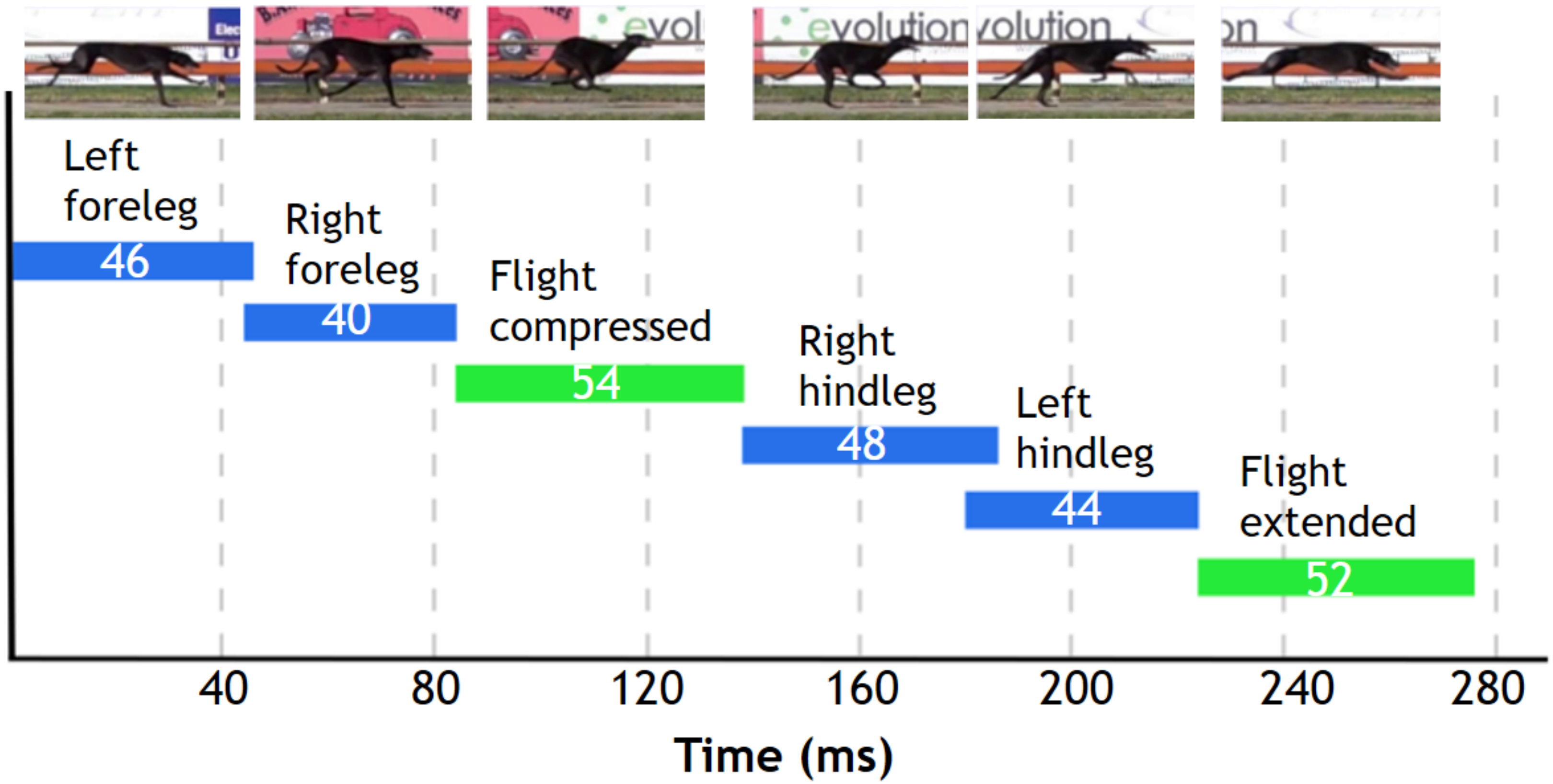
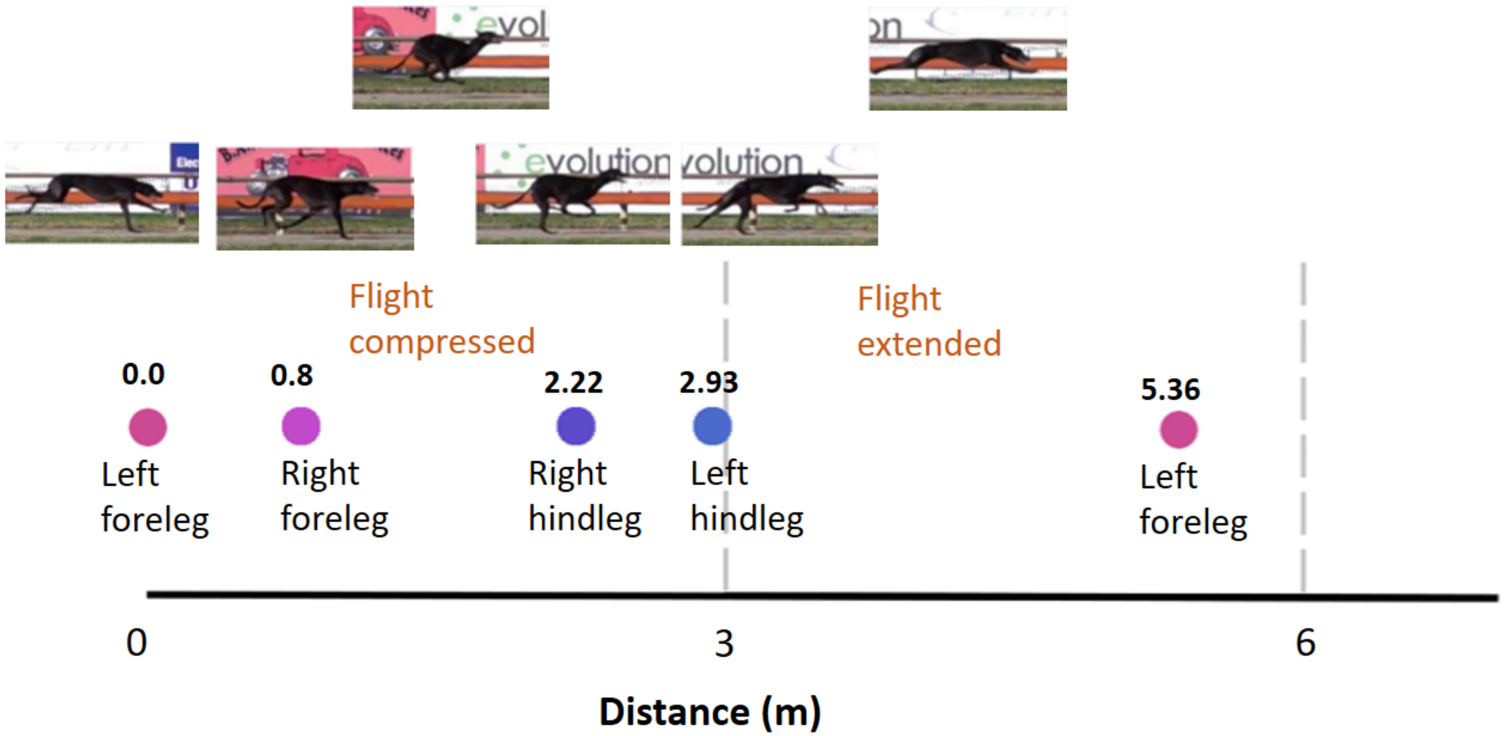
DYNAMIC MEASURMENT-KINEMATIC ANALYSIS

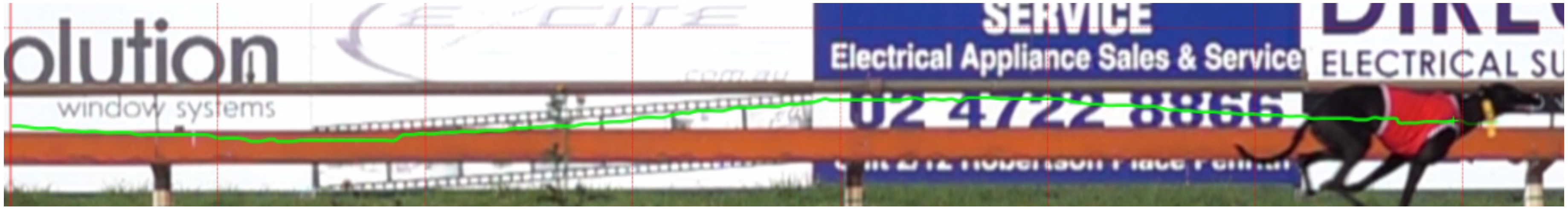


DYNAMIC MEASURMENT-KINEMATIC ANALYSIS



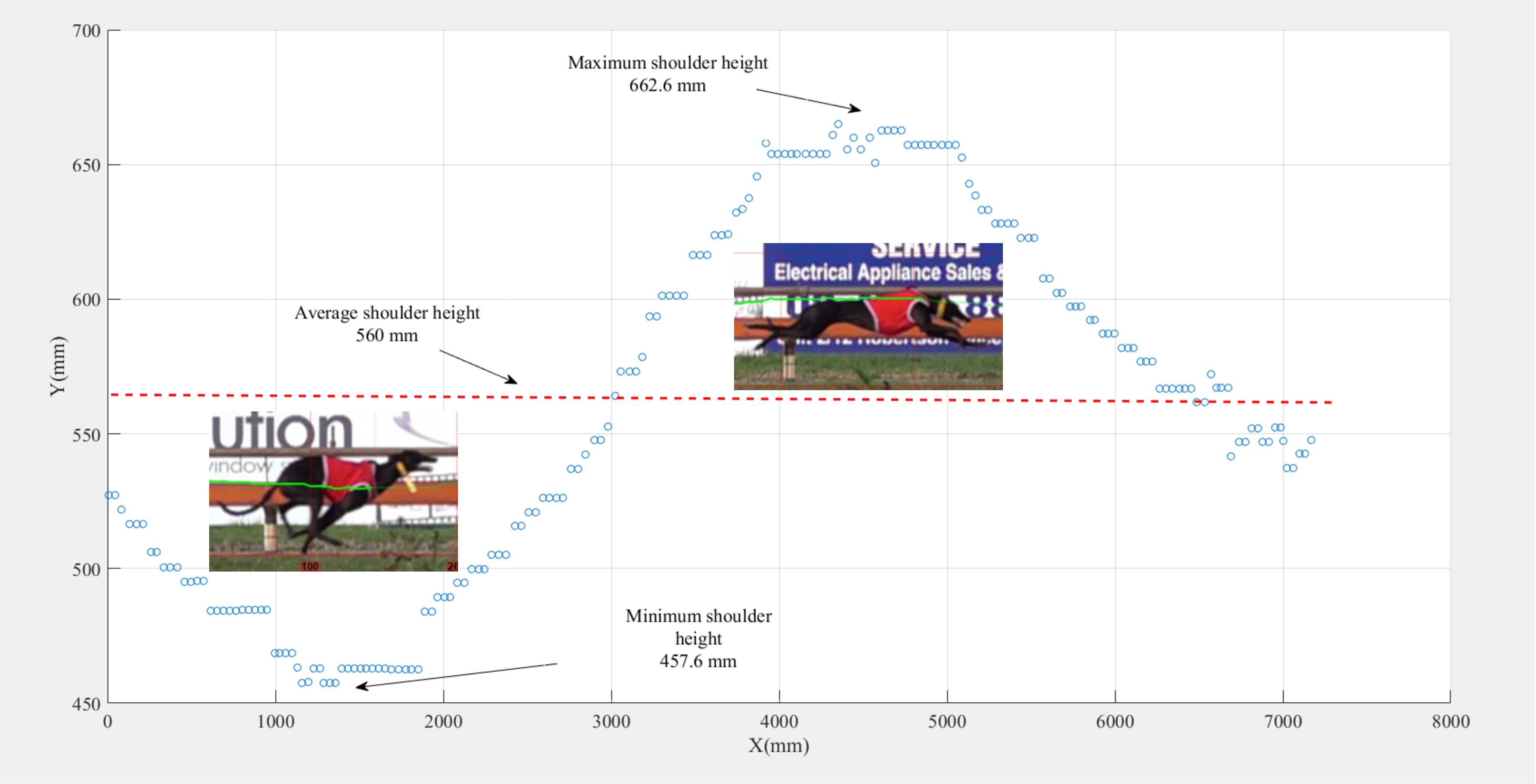
DYNAMIC MEASURMENT-KINEMATIC ANALYSIS

Shoulder trajectory line of rotatory gallop



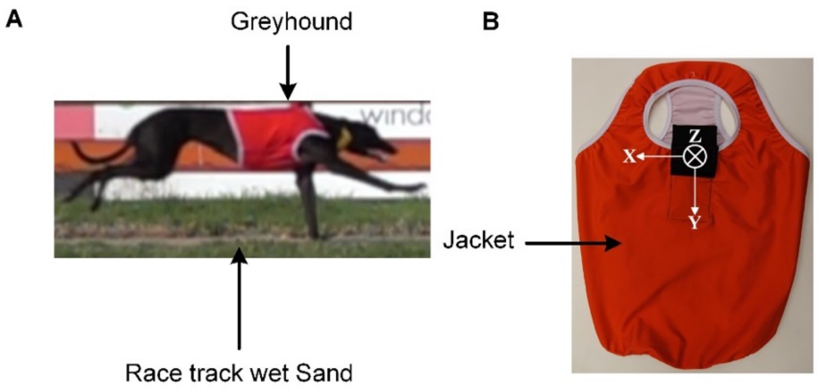
DYNAMIC MEASURMENT-KINEMATIC ANALYSIS

Shoulder trajectory line with more detail



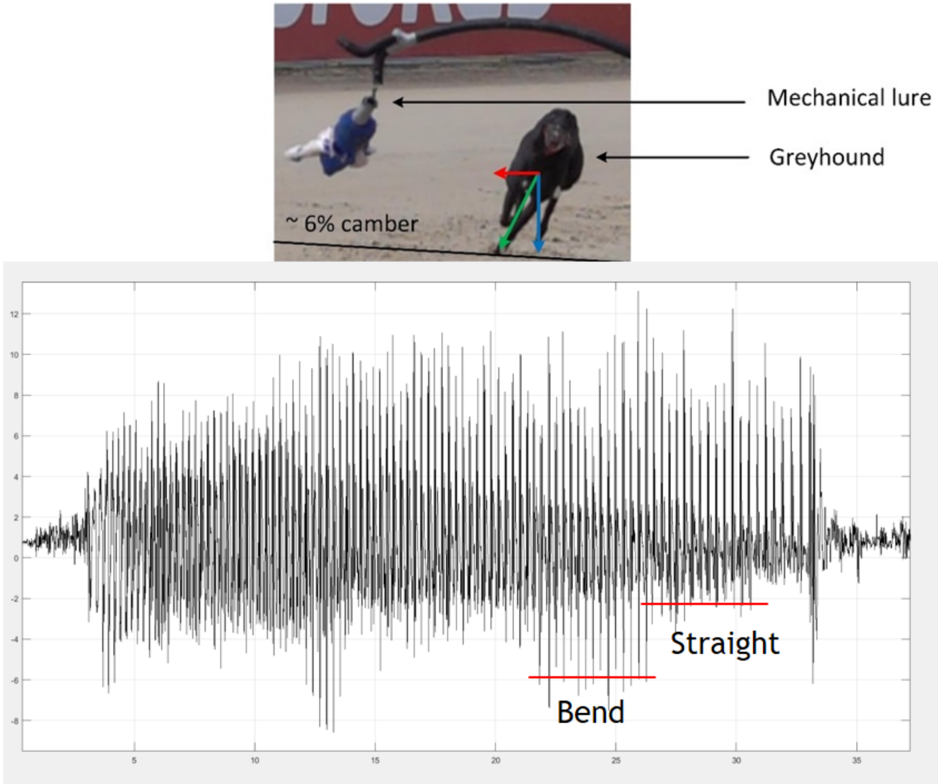
KINEMATIC MEASURMENT SYSTEM

iKMS V1.1 central acquisition unit



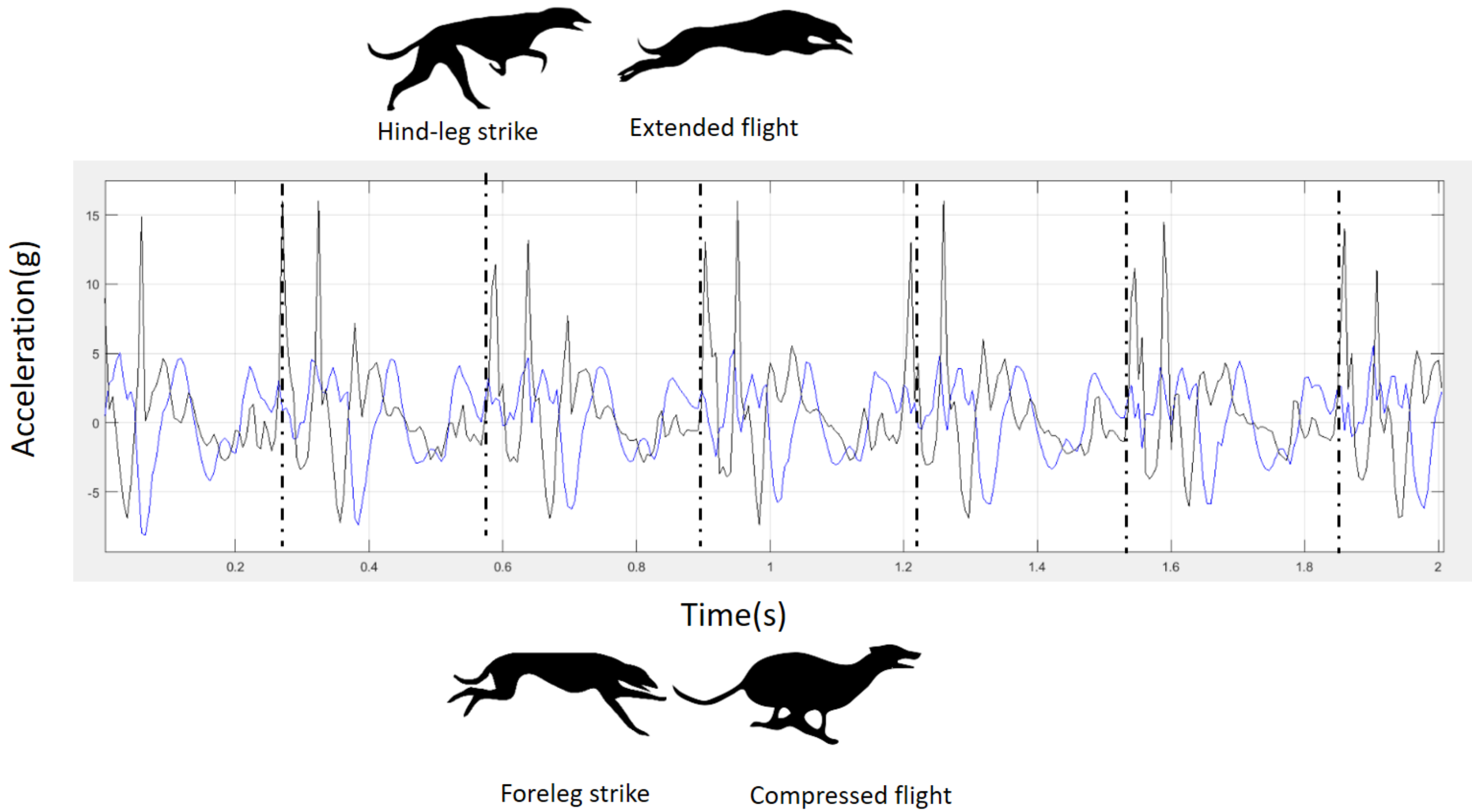
A greyhound wearing a jacket with embedded Integrated Kinematic Measurement System (iKMS)

KINEMATIC MEASURMENT SYSTEM



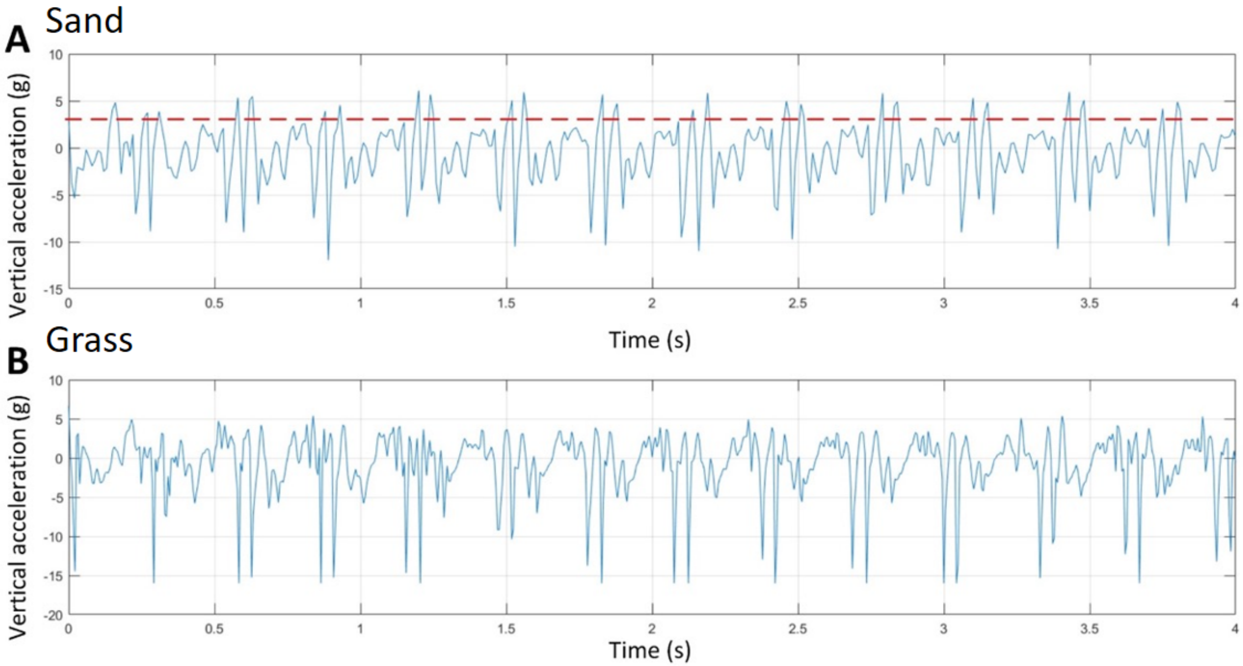
Example of Integrated Kinematic Measurement System (iKMS) raw data

KINEMATIC MEASURMENT SYSTEM



DYNAMIC MEASURMENT-KINETIC ANALYSIS

IKMS DATA TO ANALYSE THE TRACK SURFACE



Parameters	Value
Peaks of vertical acceleration (sand-bend)	7.4 g
Peaks of vertical acceleration (sand-straight)	5.0 g
Peaks of vertical acceleration (grass-bend)	7.1 g
Peaks of vertical acceleration (grass-straight)	4.3 g
Stride frequency (sand-bend)	3.60 Hz
Stride frequency (sand-straight)	3.50 Hz
Stride frequency (grass-bend)	3.85 Hz
Stride frequency (grass-straight)	3.45 Hz

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DYNAMIC MEASURMENT-KINETIC ANALYSIS

UTS PUBLISHED ARTICLES

Proceedings of the ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conferences
ASME IDETC/CIE
August 6-9, 2017, Cleveland, Ohio, USA
DETC2017-67691

A STUDY OF RAPID TETRAPOD RUNNING AND TURNING DYNAMICS UTILIZING INERTIAL MEASUREMENT UNITS IN GREYHOUND SPRINTING

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ABSTRACT
Understanding the biomechanics of rapid running locomotion plays an important role in comparative biomechanics and bio-inspired engineering and is an integral part of animal welfare.

However, this is not easily achieved using conventional methods of gait analysis: measuring ground reaction forces using a force plate, mainly on irregular granular terrain i.e. greyhounds in racing conditions or in animal's natural habitats i.e. cheetahs in natural terrain. An alternative to measuring forces externally via force platforms embedded in track ways, we can attach inertial measurement units to agile quadrupeds to measure the effects of rapid running and turning.

Here we deployed an IMU equipped with a tri-axial accelerometer on sprinting greyhounds to analyze rapid locomotion behaviors like dynamic banking and turning in conditions equivalent to racing. High speed videography and paw print analysis of the entire race were used for calibration. The results are beneficial in locomotion analysis and welfare of greyhounds.

NOMENCLATURE
EMA effective moment arm
GRF ground reaction forces
HFR high frame rate
IMU inertial measurement unit

INTRODUCTION
Human athletes run only half as fast as Greyhounds, maintaining constant average running speeds of circa 29 km/h versus 65 km/h [1], respectively. Accordingly the sudden transitions from straight-line running to a bend results in a greater frequency of accidents and injuries [2] due to the high rate of jerk and snap.

High rate of acceleration and change of rate of acceleration has made the race track a potentially hazardous area for racing greyhounds. Moreover, injuries common in race track are unique in racing greyhounds, suggesting specific types of injuries are closely correlated with race track design. This observation was previously documented by researchers [3-12].

Added to this, rapid changes in direction during running around a bend, increase the risk of injury as greater centrifugal forces act on limbs and torso [2]. Moreover, agile quadrupeds such as greyhounds are more prone to sustain injuries while negotiating around the bend than human athletes due to the extreme force upon contact of one paw in rotatory galloping gait.

Rapid quadrupedal movement on granular media and other irregular terrain is an interesting area of research which is under-explored. Current methods of studying rapid quadrupedal movement involve the measurement of GRF using a force plate and a simultaneous kinematics analysis by HFR video footage.

In a study back in 1982, greyhounds' frozen cadaver and HFR video footage of greyhound's rotatory galloping were used to measure the linear and angular acceleration of the legs. As a result the maximum stress exerted during galloping of each leg were calculated [13]. Almost three decades later cadavers of racing greyhounds were used to provide quantitative anatomical data on the muscle–tendon architecture and geometry of pelvic limb to calculate pelvic joint EMA [14]. To measure GRF associated with acceleration and deceleration of racing greyhound, six racing greyhound were encouraged to ran across a purpose-built run way consisting of downward and upward sloping ramp equipped with five embedded force plates.

Although force plate provides highly accurate kinetic data, it is not always practical to deploy in the study of animal

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ASME IEMCE 2018
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IMECE2018-87144

A COMPARATIVE STUDY OF RAPID QUADRUPEDAL SPRINTING AND TURNING DYNAMICS ON DIFFERENT TERRAINS AND CONDITIONS: RACING GREYHOUNDS GALLOPING DYNAMICS

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ABSTRACT
Identifying optimum athletic race track surfacing for greyhounds to reduce risk of injuries is a challenging practice as there are several single and coupled variables that should be considered as risk factors. To study the impact of bend and straight sections, surface type and camber, on biomechanics of galloping quadrupeds, an inertial measurement unit (IMU).

has been used to measure the associated galloping accelerations. The IMU was sewn into a pocket located on the back of the greyhounds racing jacket positioned between the two forelegs. Simultaneous kinematics were performed using high frame rate (HFR) videos for calibrating IMU data. The results showed that there were lower G-forces on galloping on grass than wet sand which is consistent with the mechanical behavior of grass (grass is softer than wet sand). Moreover, galloping around the bend had higher G-forces than galloping along the straight section suggesting an excessive force is applied on the greyhound's limbs due to centrifugal force. A cambered bend assisted the greyhounds in having a smoother gait and lower G-forces when compared to a flat bend. The results reported in this paper will not only be beneficial for the welfare of racing greyhounds, but will also contribute in the simulation of legged locomotion for bio-inspired engineering and robotics.

NOMENCLATURE
GRF ground reaction force
HFR high frame rate
IMU inertial measurement unit
NSW New South Wales

INTRODUCTION
Greyhounds can reach a speed of almost 65 km/h whereas the fastest human can only reach almost half of this (circa 29 km/h) [1]. To achieve this high speed, greyhounds must produce high muscle force mainly by their hip muscles [2,3], to accelerate and maintain their speed.

Apart from the tremendous effort required for galloping at such speed, the mechanical properties of race tracks contribute to the rate of injuries sustained by greyhounds. This has been analysed to some extent in previous studies [4–10].

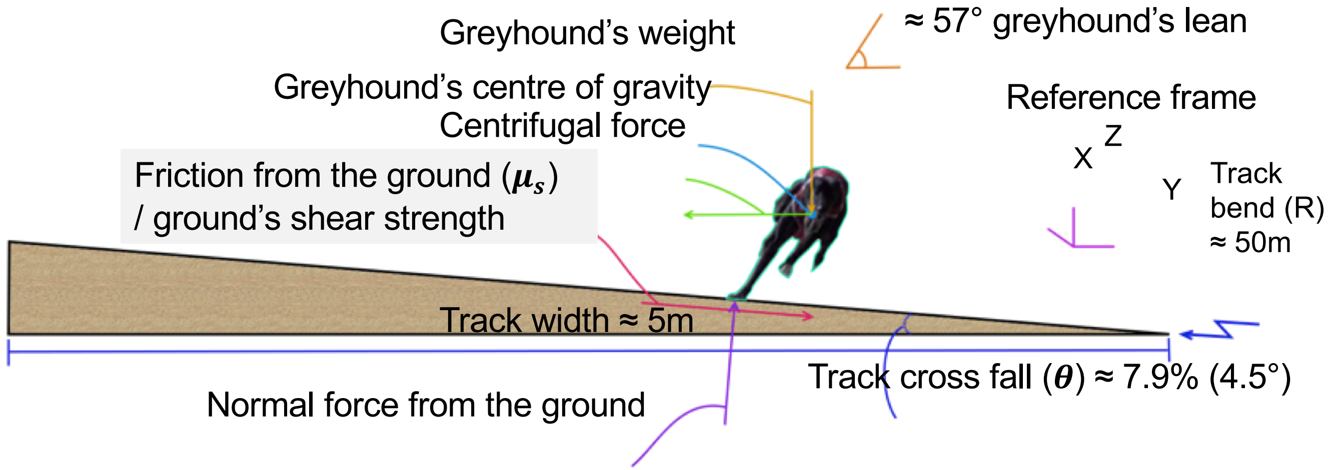
For instance, the high rate of acceleration and jerk applied to greyhounds' limbs as they are navigating around the bend [11], was shown to have an impact on their galloping dynamics as most of the injuries are seen to happen on bend sections of race tracks [10].

There are various methods of studying the underlying biomechanics of gaits. Deploying force plates to analyse asso-

TRACK SIMULATION

Greyhounds on the bends

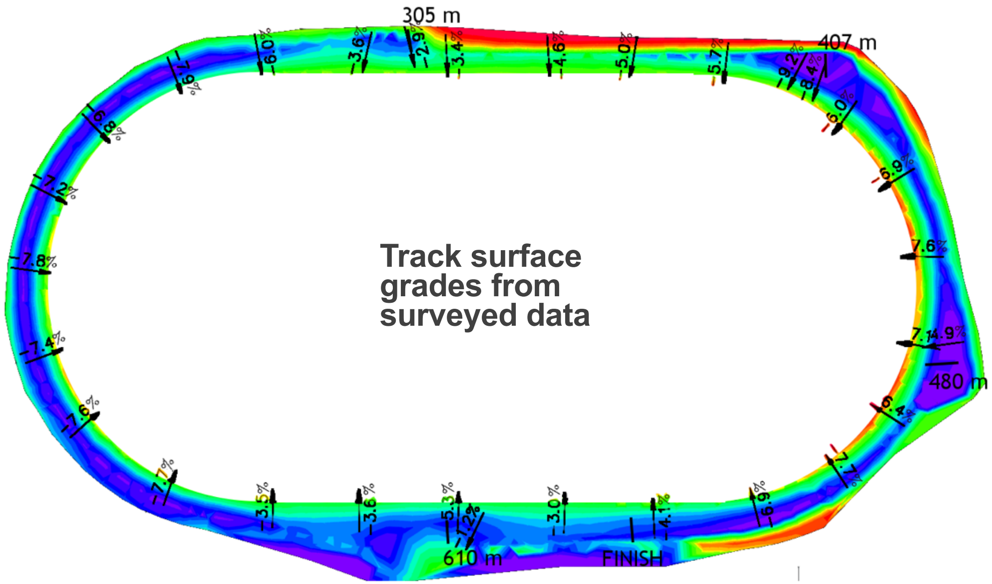
Maximum constant galloping speed possible for greyhounds	
R	Bend
g	Acceleration due to gravity
	Track's coefficient of static friction
$\boldsymbol{\theta}$	Cross fall of the track
v constant	Greyhounds maximum speed

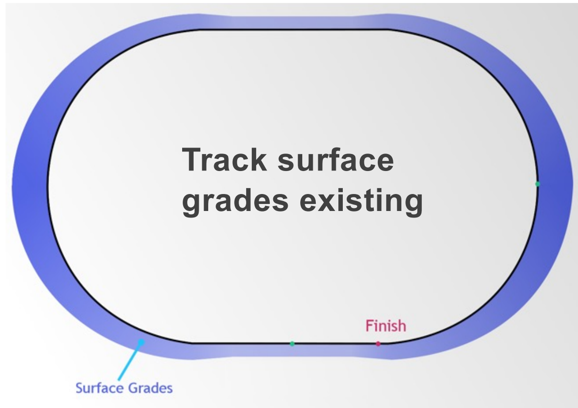


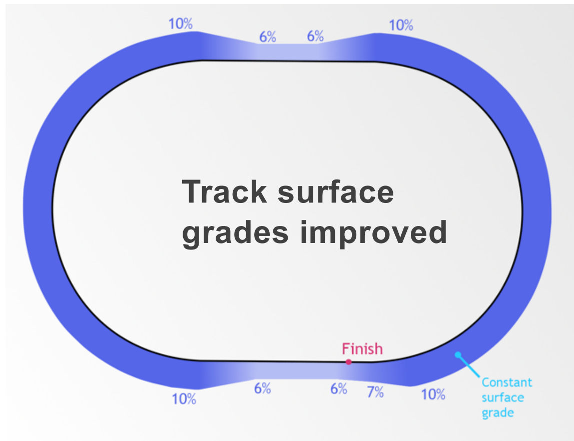
Forces acting on a greyhound on the bend front view

TRACK DESIGN INVESTIGATION

What can be done for cross falls at the tracks

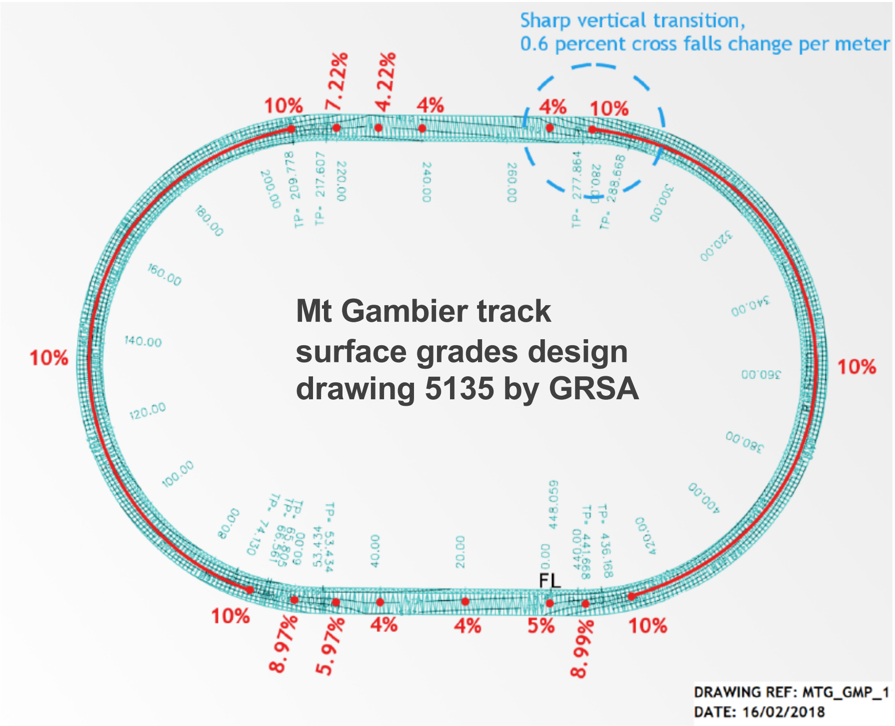


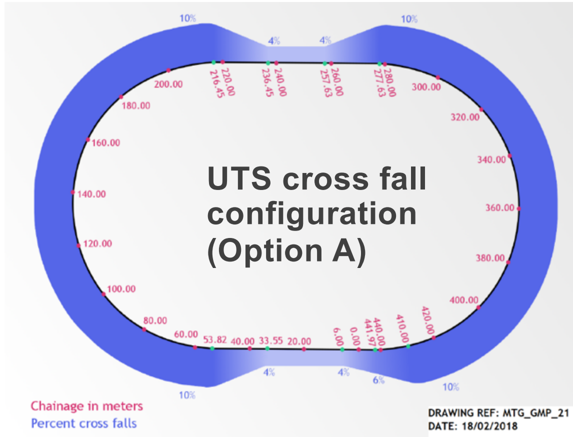


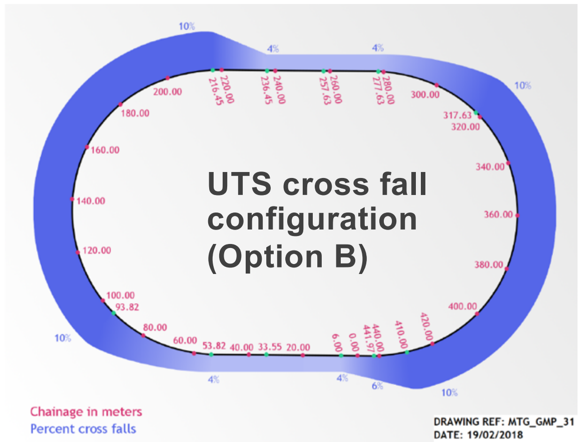


TRACK DESIGN INVESTIGATION

What can be done for cross falls at the tracks



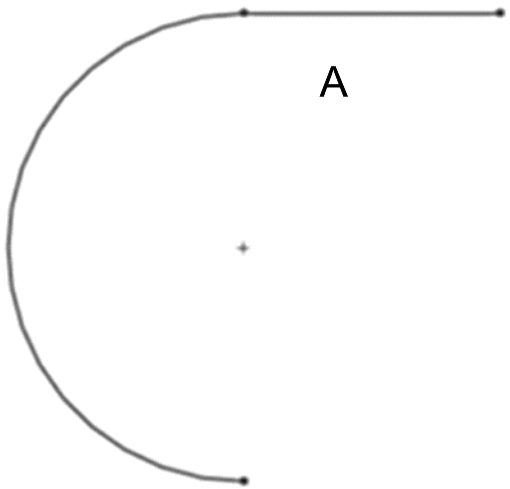




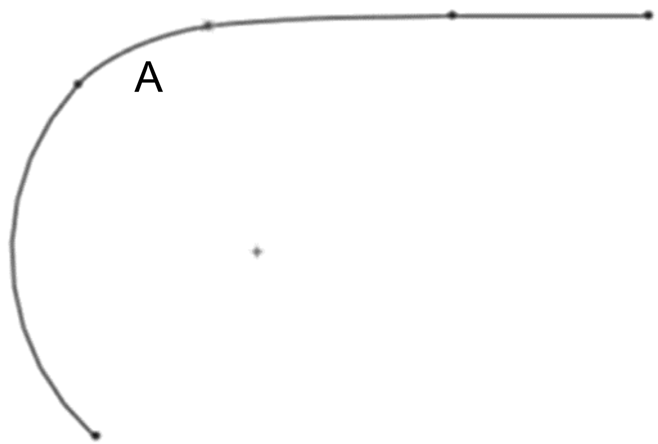
TRACK DESIGN INVESTIGATION

Continuity of a track path

First order



Second order



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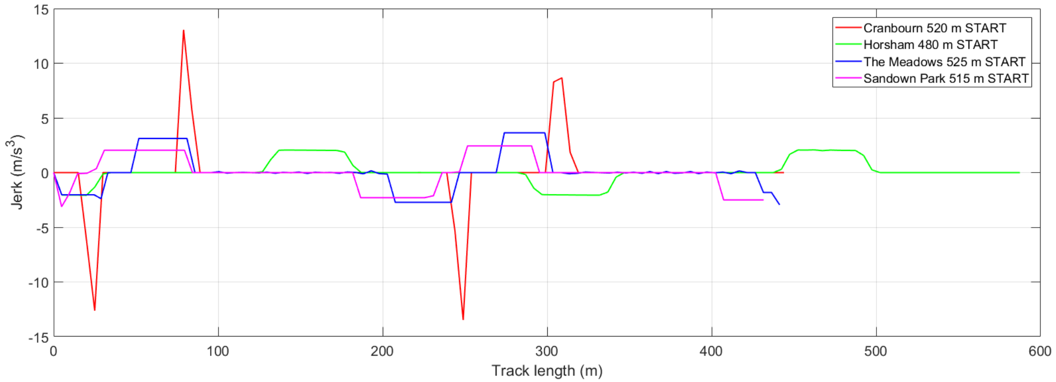
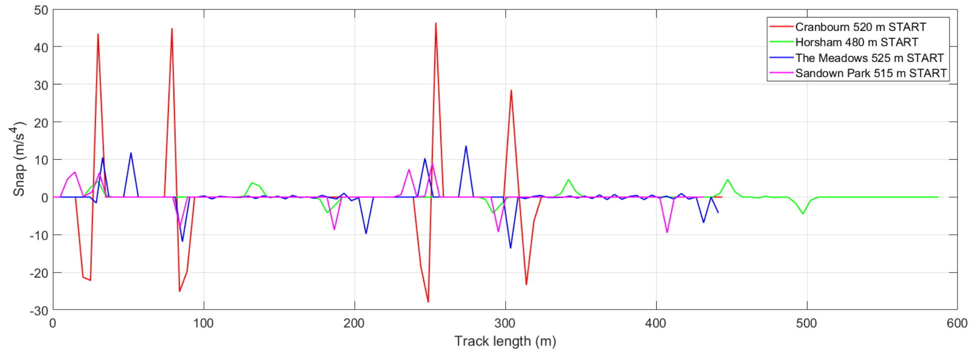
TRACK DESIGN INVESTIGATION

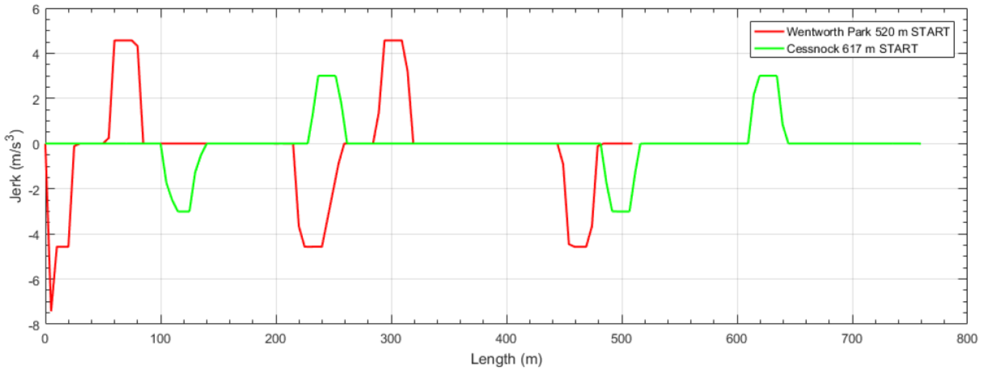
Continuity of a track path and lateral dynamics

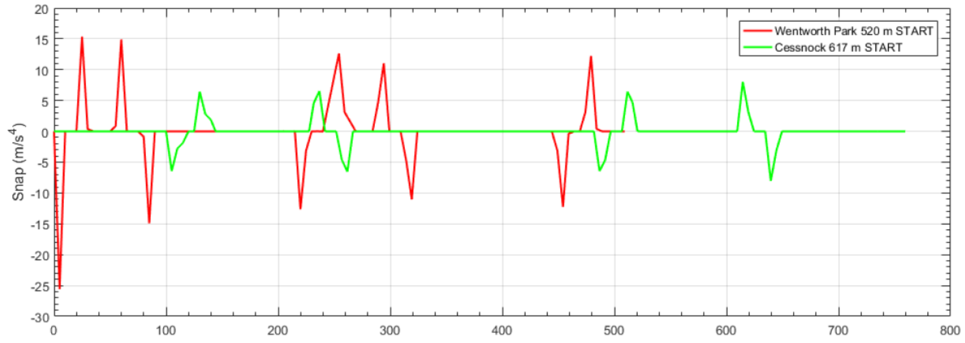




TRACK DESIGN INVESTIGATION

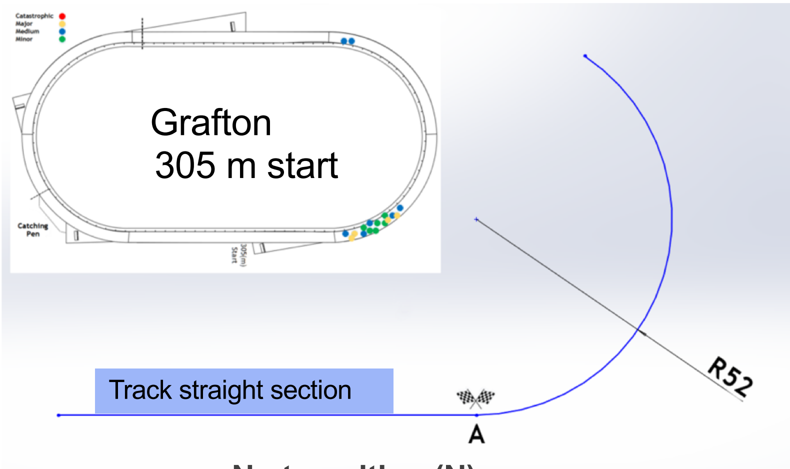
Continuity of a track path and lateral dynamics



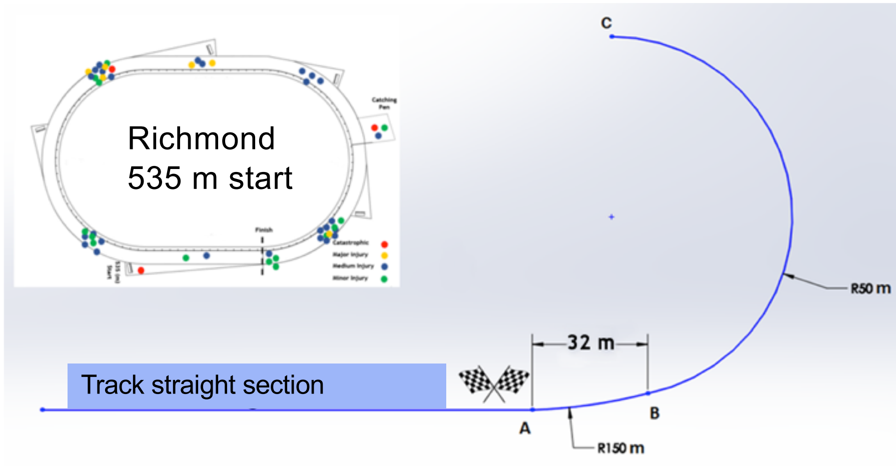


TRACK DESIGN INVESTIGATION

Straight to bend path types in GRNSW tracks



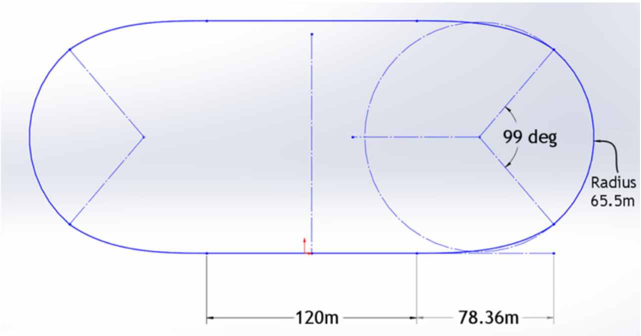
No transition (N)



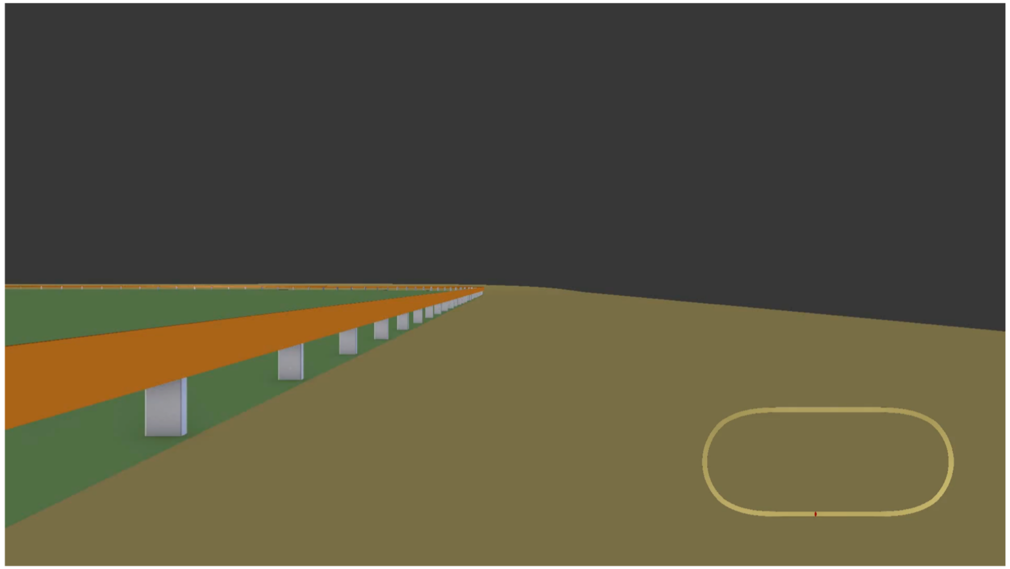
Part transition (P)

TRACK DESIGN INVESTIGATION

Straight to bend path with proper Euler transition



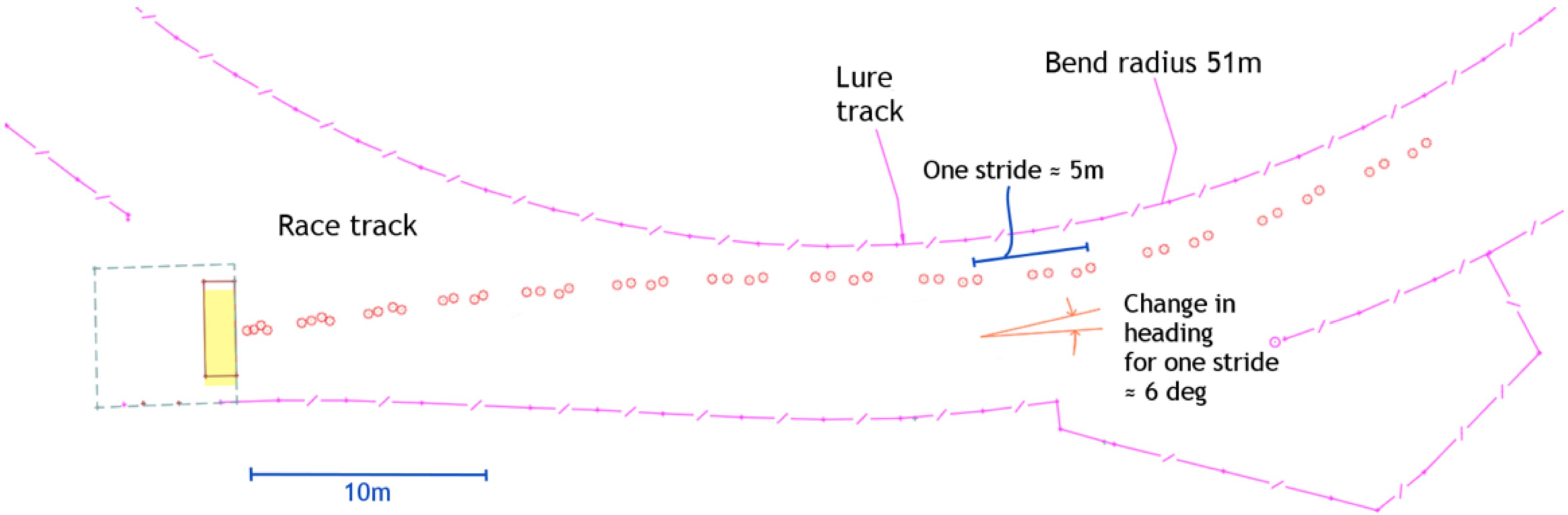
Hypothetical track design with minimal centrifugal acceleration jerk (plan view)



Greyhound run video for hypothetical track with minimal centrifugal acceleration jerk (greyhound view)

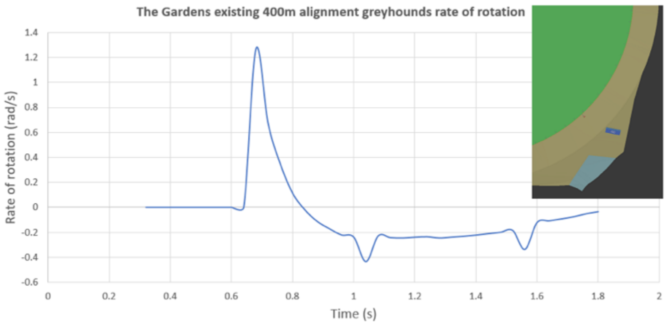
TRACK DESIGN INVESTIGATION

Rate of rotation (yaw rate) of greyhounds for Richmond 400 m starts immediate bend

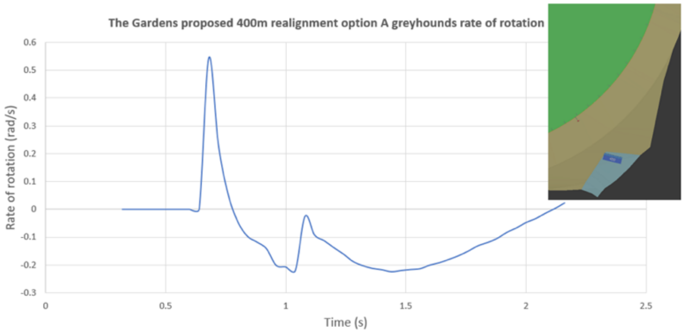


TRACK DESIGN INVESTIGATION

The Gardens starting box alignment



Old boxes alignment

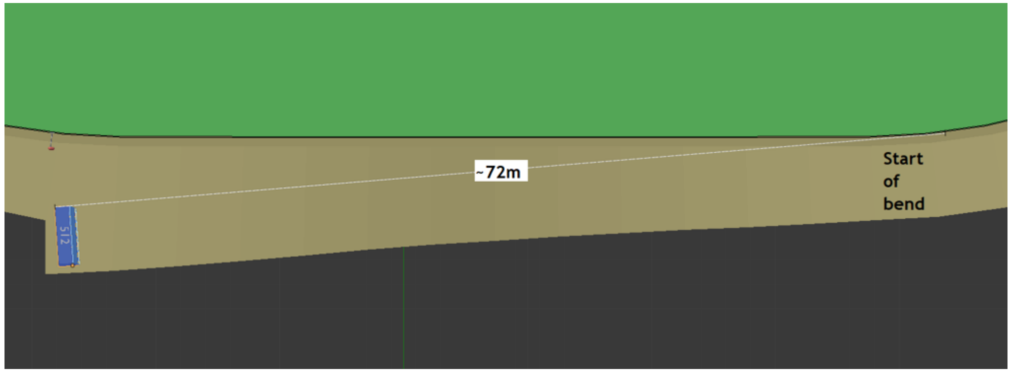


New boxes alignment (proposed)

Starting boxes realignment options for 400 m start

TRACK DESIGN INVESTIGATION

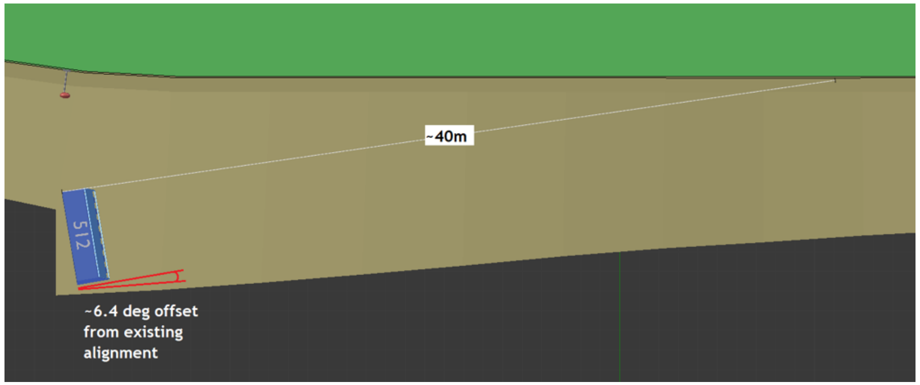
Mt Gambier starting box alignment



Old boxes alignment

Maximum transitional rate of rotation

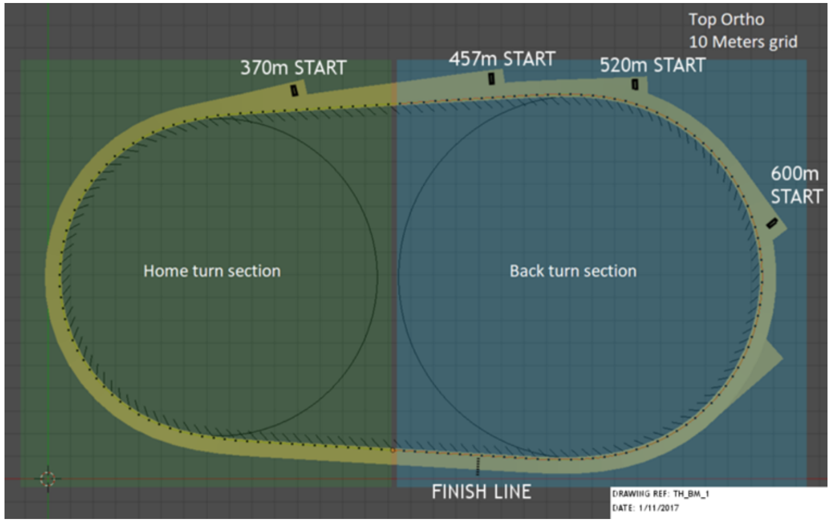
Boxes alignment for distance start	Rate of rotation (rad/s)
Existing 512 m	2.63
Improved 512 m	1.73



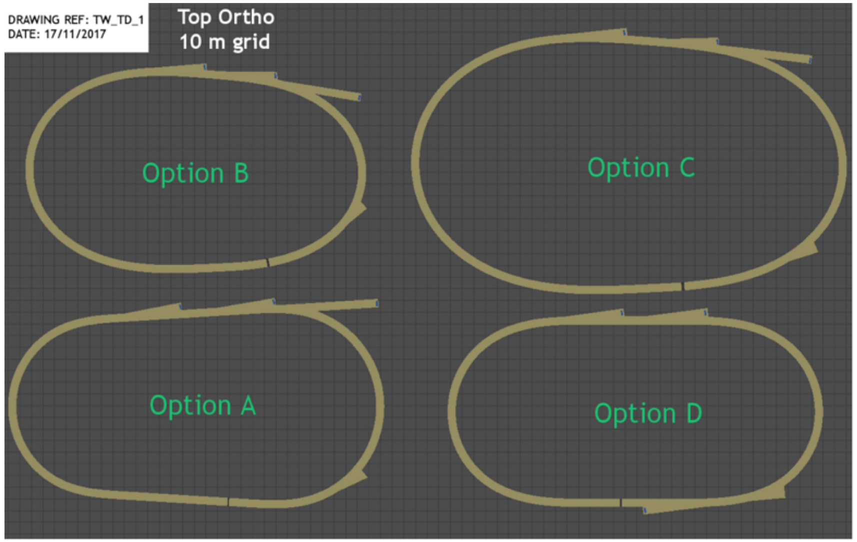
New improved boxes alignment

TRACK DESIGN INVESTIGATION

Alternative design options for Tweed Heads



Tweed Heads track design proposed by club

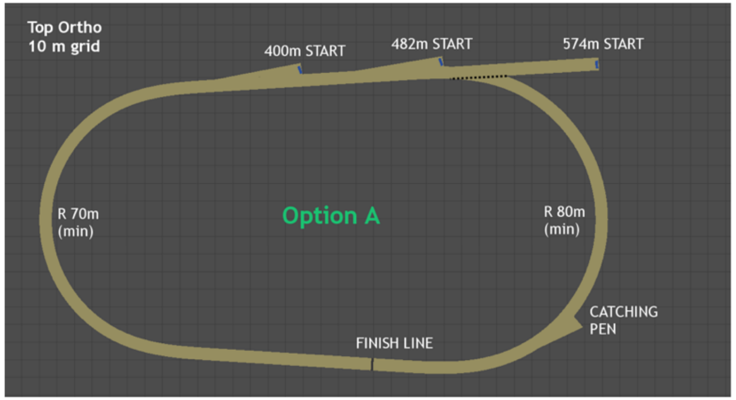


Tweed Heads design developed by UTS

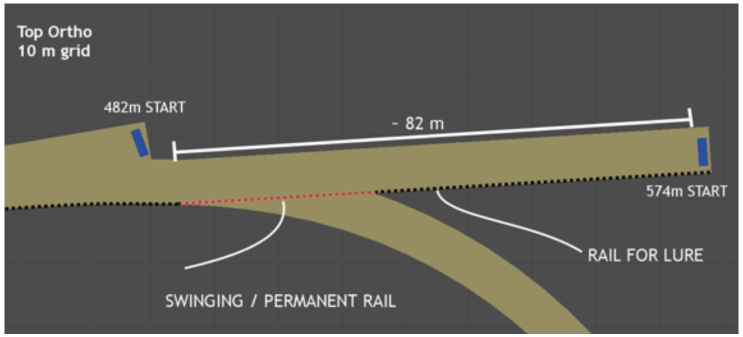
Track design	Jerk magnitude (m/s^3)
Alternative design Option C	0.42
Alternative design Option B	0.72
Alternative design Option D	1.1
Alternative design Option A	1.69
Richmond	5.5
Wentworth Park	10.5

TRACK DESIGN INVESTIGATION

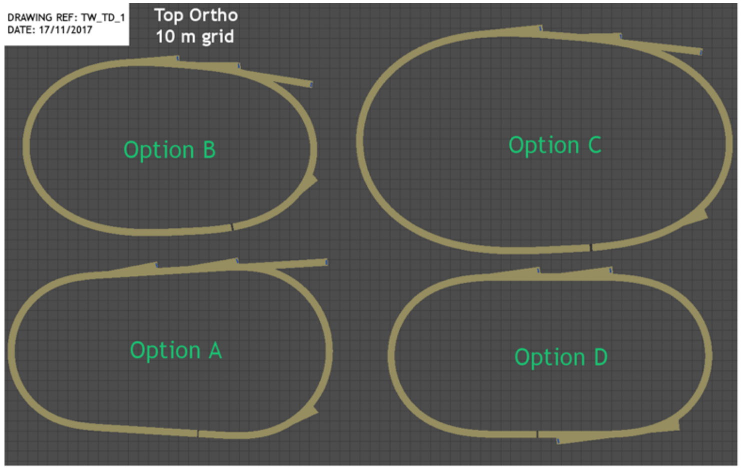
Alternative design options for Tweed Heads



Tweeds Head proposed design by UTS

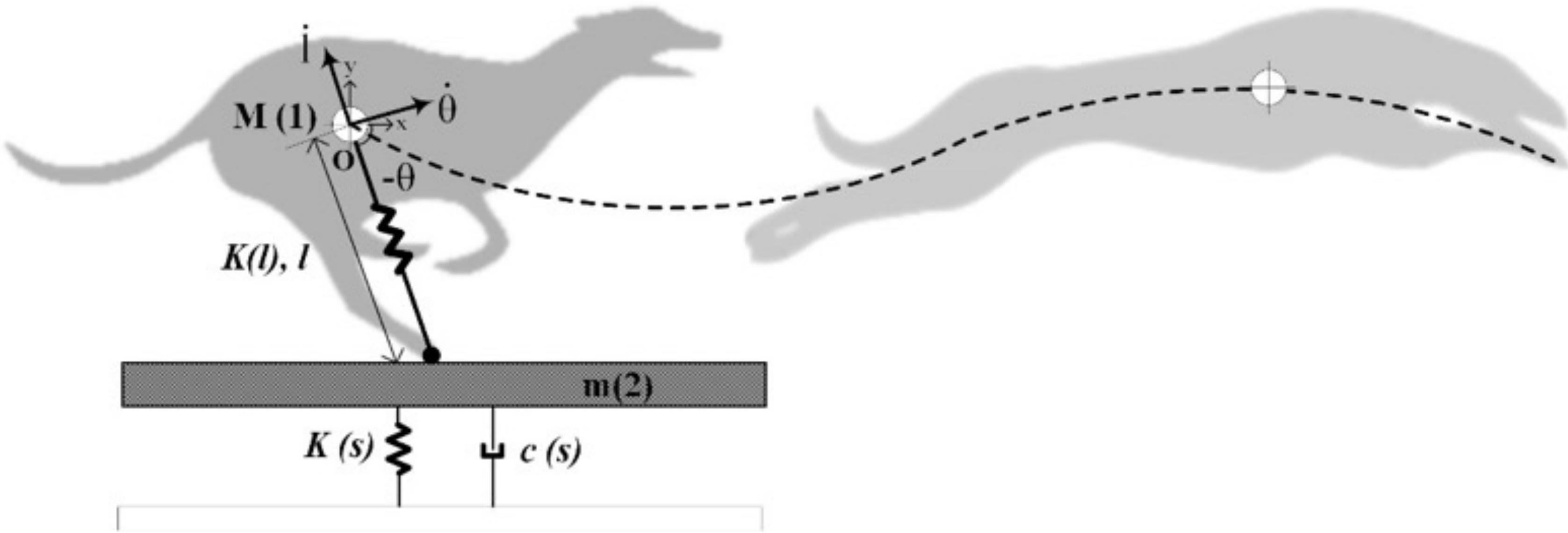


Tweeds Head proposed design by UTS with extended straight start

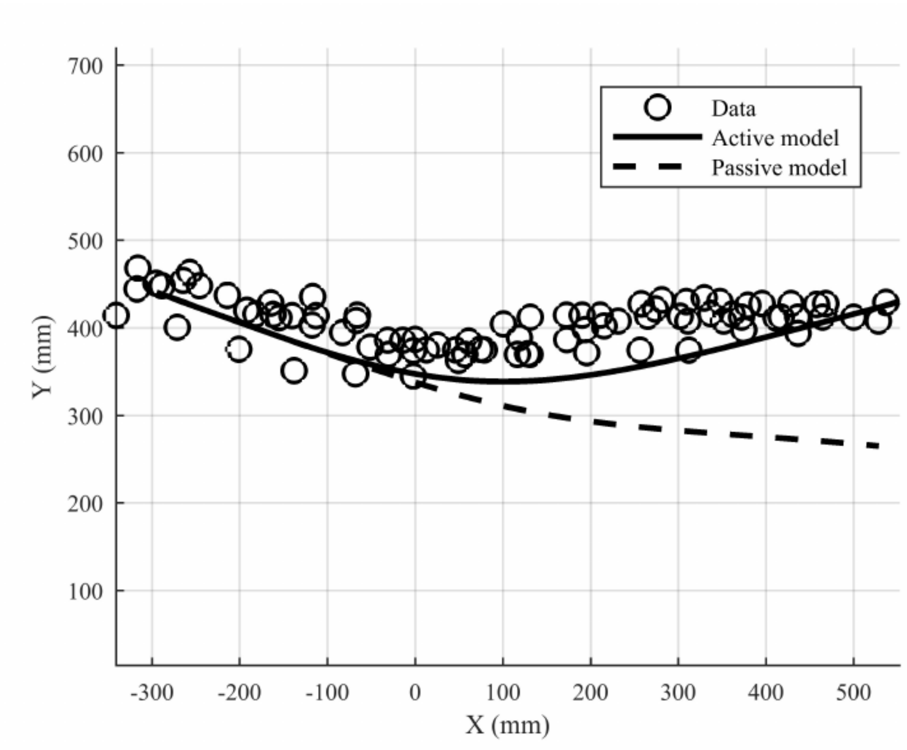


Tweed Heads design developed by UTS

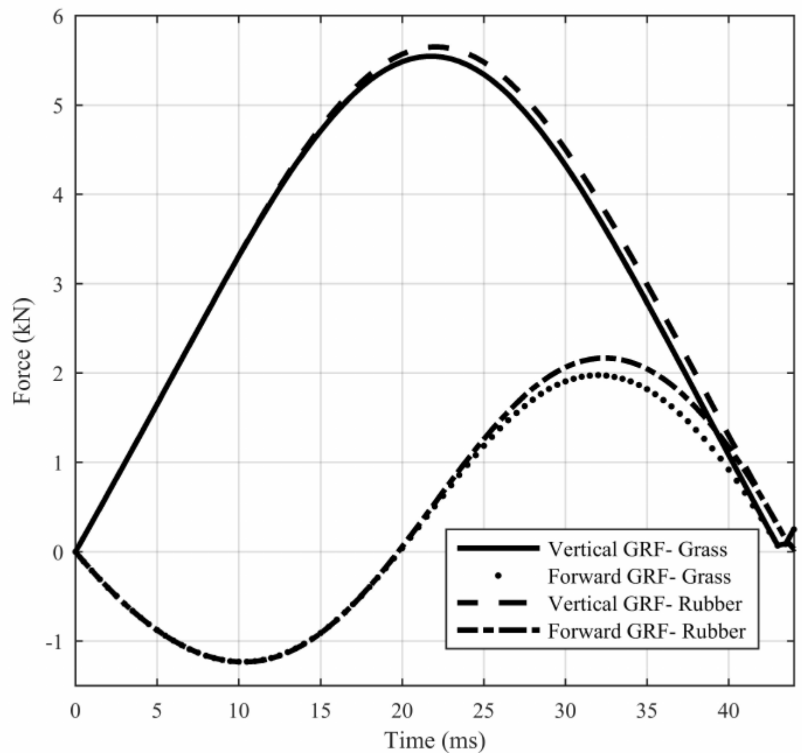
GREYHOUND'S BIOMECHANICS



GREYHOUND'S BIOMECHANICS

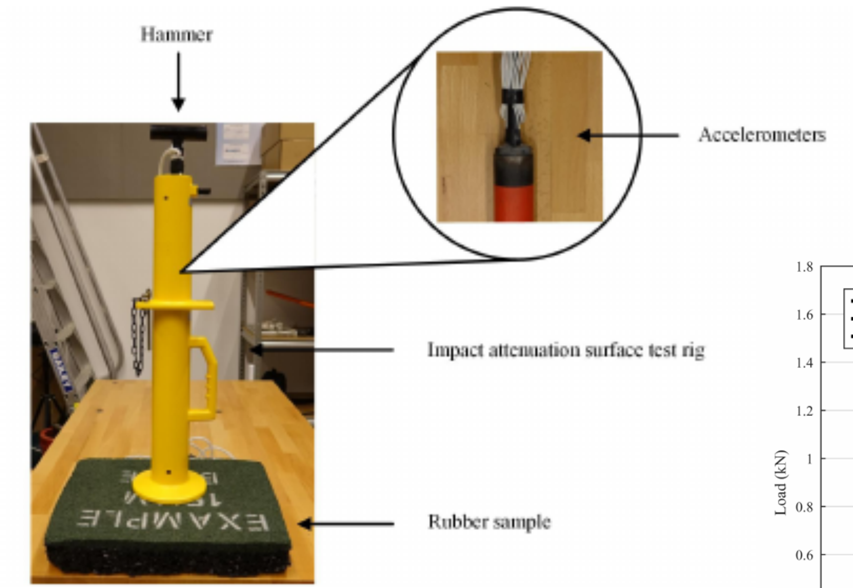


COM trajectory line of hind-leg in quadrupedal galloping of 3 DOF SLIP model and real data

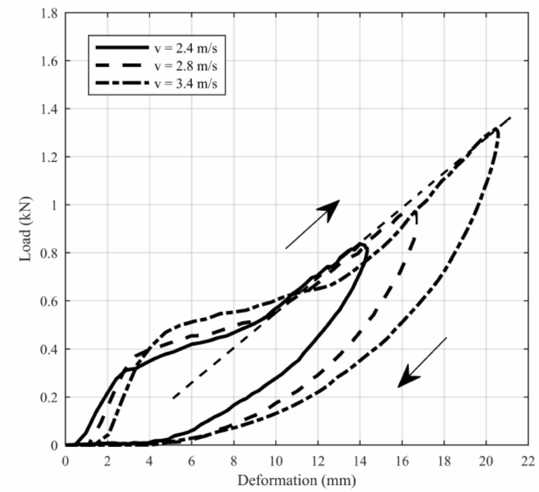


Ground reaction forces in quadrupedal galloping over natural grass and synthetic rubber

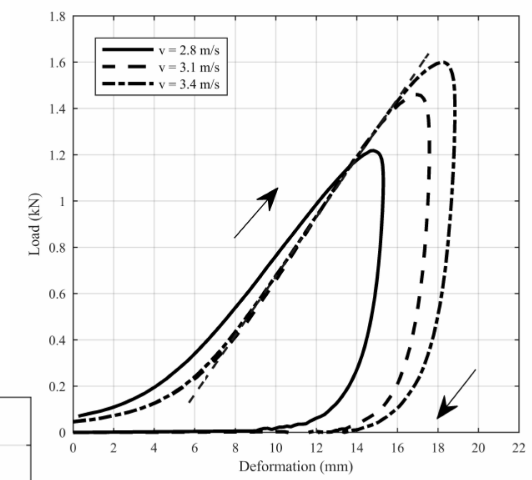
GREYHOUND’S BIOMECHANICS



Impact attenuation surface test rig (Clegg hammer)



Load-deformation cycles for synthetic rubber terrain for impact velocities of 2.4 to 3.4 m/s.



Load-deformation cycles for synthetic grass terrain for impact velocities of 2.8 to 3.4 m/s.

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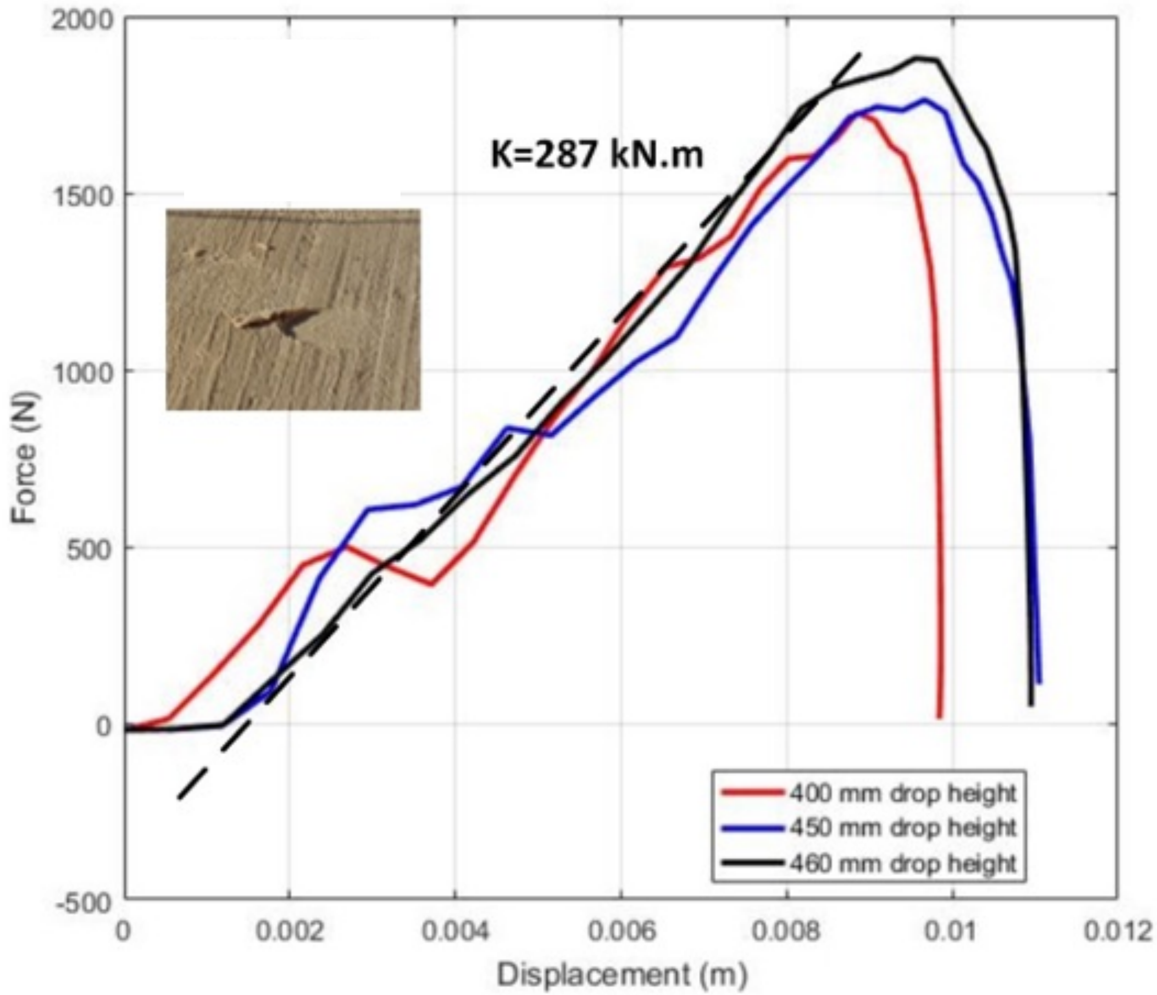
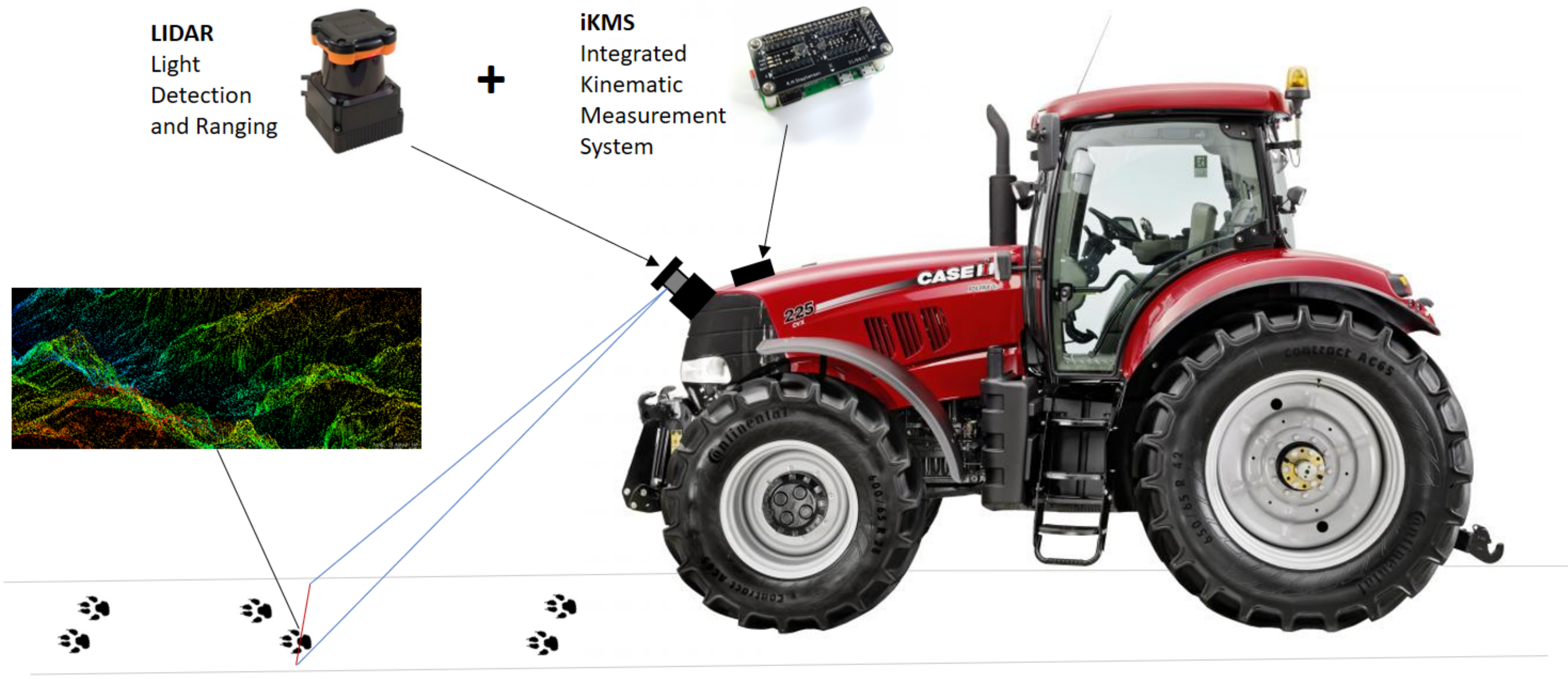
GREYHOUND'S BIOMECHANICS



ADVANCED 3D PAW IMPRINT RECONSTRUCTION



ADVANCED 3D PAW IMPRINT RECONSTRUCTION

- Paw imprints can be seen as an objective measurement of track surface properties
- It is hypothesised that optimum paw imprint will allow standardisation of current track surface analysis techniques such as penetrometer, moisture and impact testing
- Print shape and depth may be correlated with variables such as compaction and moisture content
- Change of surface preparation philosophy: Instead of changing variables to chase performance the greyhound racing industry chooses the performance and change the variables accordingly
- Analysis may concluded that different surfacing properties are required where the greyhounds are subjected to different forces ie bend and straight may require different sand, moisture and/or preparation to optimise the performance
- Additionally, paw imprint reconstruction allows analysis of previously unobtainable stride, gait and surface information

AUSTRALIAN AND NEW ZEALAND STANDARD GREYHOUND TRACKS DESIGN

- Should one of the greyhound industry's goals be to write and publish a **joint Australian and New Zealand Standard**?
- Scope of this Standard would be to specify the minimum safety requirements for greyhound race and trialing track design?
- A joint national Standard would codify the requirements for greyhound safety and welfare in a transparent manner while allowing the public input into the process
- Standards Australia and New Zealand would require **consensus** from a broad spectrum of organisations
- Standards Australia and New Zealand would require the draft Standard to go through a **9 week public comment phase** and where all comments are resolved before publication

PUBLICATIONS & PRESENTATIONS

- Hayati H., Eager D., Walker P., Rapid quadrupedal locomotion, ABC11, Australian and New Zealand Biomechanics Society, Auckland, New Zealand, 3-5 December 2018
- Hayati H., Walker P., Brown T., Kennedy P., Eager D., A simple spring-loaded inverted pendulum (SLIP) model of a bio-inspired quadrupedal robot over compliant synthetic terrains, ASME-IEMCE 2018, American Society of Mechanical Engineers, Pittsburgh, Pennsylvania, USA, 9-15 November, 2018
- Hayati H., Walker P., Mahadavi F., Stevenson R., Brown T., Eager D., A comparative study of rapid quadrupedal springing and turning greyhounds galloping dynamics, ASME-IEMCE 2018, American Society of Mechanical Engineers, Pittsburgh, Pennsylvania, USA, 9-15 November, 2018
- Mahadavi F., Hossain I., Hayati H., Eager D., Kennedy P., Track shape, resulting dynamics and injury rates of greyhounds, ASME-IEMCE 2018, American Society of Mechanical Engineers, Pittsburgh, Pennsylvania, USA, 9-15 November, 2018
- Eager D., Australian Greyhound Veterinarians Conference, Melbourne, 9 October 2018
- Eager D., UTS greyhound safety and welfare research, Maitland Greyhound Club, Maitland, 09 September 2018
- Eager D., Quantifying the surface properties of greyhound racing tracks, Greyhound Racing NSW Curators Conference, Sydney, GRNSW, 14-15 July 2018

PUBLICATIONS & PRESENTATIONS (CONT)

- Eager D., Measuring track properties for performance and safety, Greyhound Racing Victoria Track Managers Conference, Warragul, 9 July 2018
- Eager D., UTS track research for greyhound safety and welfare, Greyhound Australasia, Sydney, 12 June 2018
- Eager D., UTS greyhound safety and welfare research, Grafton Greyhound Club, Grafton, 03 June 2018
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- Eager D., UTS greyhound safety and welfare research, Greyhound Racing NSW, Rhodes, 11 September 2017
- Hayati H., Eager D., Jusufi A., Brown T., A novel approach to analysing rapid tetrapod locomotion using inertia measurement units and stride length as a speed indicator in fast quadrupeds, International Society of Biomechanics, Brisbane, Australia, 23-27 July 2017
- Hayati H., Eager D., Jusufi A., Brown T., Stride length as a speed indicator in fast quadrupeds, International Society of Biomechanics Conference, Brisbane, Australia, 23-27 July 2017
- Jusufi A., Hayati H., Eager D., Tucker B., Exploration of Rapid Tetrapod Running Performance utilizing Inertial Measurement Units, 8th Adaptive motion of animals and machines, Sapporo, Japan, 27-30 June 2017
- Eager D., UTS track research for greyhound safety and welfare, Greyhound Australasia, Perth, 3 March 2017
- Eager D., Identifying optimal greyhound track design for greyhound safety and welfare, GRNSW Veterinary Conference, Sydney, 26 February 2017

FUTURE WORK

- **Data analysis**
  - AI and machine learning to identify sources of injuries and design optimised tracks
- **Dynamics measurement**
  - Refine iKMS device and associated software
- **Racing simulation software**
  - Using actual race data train software to identify dog behaviour such inside and outside runners
- **Greyhound biomechanical simulation**
  - A complete cycle of a galloping greyhounds will be modeled
- **Track surface analysis**
  - LIDAR to map paw prints coupled with the dynamic properties of the sand to optimise surface
- **Greyhound position tracking**
  - GPS device to accurately track greyhound location from cradle to rehoming

Thank

You