Safety challenges of connected and autonomous vehicles

Workshop on Dynamic Testing for Autonomous Systems
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- Transport and mobility research is a major theme across the University
- Over 140 academics conducting transport/mobility related research
- One of 5 Beacon research themes
- Key Schools include
  - Design School – safety, field trials and human factors
  - Aero/Auto – Autonomous systems
  - Civil and Building – Transport simulation and analytics
  - Computer Science – Networks, computational intelligence and cyber-security
Smart Mobility Living Lab: London

- From 2017
- New world-class test bed for CAV
- Loughborough is academic lead
- New teaching and research programme in CAV
CAV research at Loughborough

- Basic science and technology research
  - Connected systems
  - Autonomous systems

- Real-world implementation and evaluation
  - Field trials
  - Safety
  - MaaS
  - Impact studies
    - Environment
    - Congestion
    - User acceptance
Connected systems

- Communications – V2X, ad-hoc networking
- Network simulation
- Environment and traffic modelling
- Transport analytics
- Transport modelling
- Map matching
Autonomous systems

- Integration of sensor and control systems
- Computation intelligence and machine perception
- Verification and validation
- Development of control algorithms
- Uncertainty
- Vehicle dynamics
- Applications to UAV and road vehicles
Field trials and evaluations

- Real-world testing of PODs and CAVs
- System functionality
- Human factors and road user behaviour
- Impact on safety, environment and efficiency
- Events investigations
- Provision of London test environment
- Application areas
  - Mobility services
  - Fleet management
  - Autonomous vehicles
  - .....
Safety of connected and autonomous vehicles

RESEARCH CHALLENGES
Future mobility

Fernando Livschitz of Black Sheep Films
What is safety?

- Use of new technologies to reduce existing road risks - >reducing casualties below existing numbers
  - AEB
  - Pedestrian detection

- Management of the introduction of new technologies to avoid the introduction of new risks - > maintaining existing casualty numbers
  - exchange of control, limitations of functionality.....
Road safety in the UK

EU fatality rate

Deaths per million population

Malta, United Kingdom, Sweden, Denmark, Netherlands, Spain, Finland, Germany, Ireland, Austria, EU, Italy, Slovenia, Cyprus, France, Slovakia, Portugal, Estonia, Czech Republic, Hungary, Belgium, Luxembourg, Greece, Croatia, Poland, Lithuania, Bulgaria, Romania, Latvia

CARE: 2014
Road safety in the UK

Fatality reduction %

2000-2009

2010 - 2014
National mobility priorities

• Road safety is a matter of national importance.....The government is committed to investing in national road safety.

• Human error is reported to be a factor in 94% of road collisions, so driverless cars have huge potential to improve road safety

• KPMG report to SMMT – 2,500 deaths and 25,000 serious injuries prevented between 2014 - 2030

.................................but how will this happen?
Research challenges
New safety priorities

1. Urban safety technologies to prevent pedestrian, car occupant, PTW and cyclist crashes

2. Rural roads – car occupants and PTW riders

3. Improving M’way safety, while valuable, does not address the most common groups of casualties.
Improved vehicle crashworthiness

- 1995 - Legislative crash tests
- 1997 – EuroNCAP consumer information
- Risk of serious injury has reduced by ~60%
Crash avoidance technologies

- Anti-lock braking
- Electronic stability control
- Autonomous Emergency braking (City, inter-urban)
- Lane keeping/change
- ........
Research Challenges
Maximising safety

• How can we maximise safety through combining crash prevention and injury mitigation technologies?

• How should we modify the crash protection standards with increasing automation?
  - Reduced collision speeds (AEB)
  - Different crash configurations (autosteer)
  - Different vehicles (pods, light weight electrical)
Our key priorities for road safety include:

- Adopting the Safe Systems approach. This is clear in the framework we have set with Highways England and which it is now implementing. It is also a theme that runs throughout this Statement;
- Protecting vulnerable road users, including pedestrians, cyclists, motor cyclists and horse riders, through infrastructure and vehicle improvements, promotion of safer behaviour and equipment and ensuring other road users are aware of the risks posed to these groups and adapt accordingly;
- Taking tough action against those who speed, exceed the drink-drive limit, take drugs or use their mobile phone while on the road;
- Ensuring that the driver testing and training regime prepares new drivers for a wide range of real life driving conditions and situations;
- Working with the insurance industry to incentivise safer behaviours and to reward the uptake of those new technologies and opportunities to improve skills that are proven to reduce collisions;
- Helping employers to reduce road related collisions at work, including through improved heavy goods vehicle (HGV) safety;
- Encouraging the faster uptake of safer vehicles via the promotion of clear consumer information and the procurement of safer vehicles;

- Promoting the development and adoption of connected and autonomous vehicle technologies in a way that maximises safety benefits;
Increasing automation

Urban mobility
• Low speed, high automation
  • Cyber cars
  • Automated buses

Private vehicles
• Higher speeds, progressively higher automation
  • Based on existing technologies (ABS, ESC, LDW, LKA, FCW, ACC etc.)
  • Movement to traffic jam assist, autopark, highway chauffeur, highway autopilot
What could possibly go wrong?

Self-driving bus involved in crash less than two hours after Las Vegas launch

A truck driver is blamed for the accident, which passengers say could have been avoided if the autonomous vehicle had only reversed.
Research challenges

Monitoring deployment

- What is the real-world safety benefit of autonomous systems?
- What levels of automation give us the greatest societal benefit?
- How can we monitor their introduction properly to inform further development
  - Measuring accident reductions when vehicles are equipped with new systems
  - Measuring how systems perform in normal use
  - Providing feedback to industry and policy-makers
  - Transition phase will be 20+ years

Impact on
- Safety
- Mobility
- Environment
Real-world impact on mobility, safety and environment

- Evaluating effectiveness of safety systems
- Quantifying impact on mobility
- Monitoring deployment of ADAS and CAV
- Estimating environmental and health impacts
Field trials and system evaluation

- Evaluation of
  - Automated delivery service
  - Anywhere to anywhere shuttle

- Focusing on
  - System functionality
  - Impact on safety, environment and efficiency
  - HMI
  - Events investigations
  - Legislative requirements
  - Provision of London test environment
Research Challenges
Human factors

- How do we maximise consumer acceptance of automated systems?
- How can the transfer of control between human and system be managed safely?
- What are the implications for driver training and rules of the road?
- How do we design AV systems that are supportive for all road users?
- How can we design systems that compensate for human limitations and do not introduce new risks?
- How are AV systems used in real driving?
Driver behaviour

• Evaluating the ways in which people use ADAS and future systems
• Unobtrusive observations of driver behaviour and traffic interactions
• Link with accident causation?
Verification and validation

- How do we ensure new systems operate according to design and do not add to crash risk?

- Certification and verification for real-world driving events
  - High risk, low frequency – accidents
  - Low risk, high frequency – normal driving
  - Human driver is replaced by human software engineer
  - What is the driving test for AVs

- Demonstrations under realistic test conditions
  - Simulator studies
  - Proving ground
  - Instrumenting the real-world – CAV test beds
Virtual assurance procedures

- Sensing
- Decision making
- Control
What are the limitations of new systems?

• How do they compare to human drivers?
Comparison with passive safety

1974 – steering column
1974 – seats
1978 – head restraints
1989 – truck side guards
1991 – seat belt use
1992 – glazing
1994 – UK NCAP
1996 – side impact
1996 – front impact
1997 – EuroNCAP
2000 – front underrun
2009 – pedestrian
2012 – GSR

New regulations, technical progress
Validation challenges

- Public wants assurance automated vehicles are safe
- ........in every driving situation
- ........not 99% or 99.9999%
- Many, many permutations
  - Road characteristics
  - Environmental characteristics
  - Vehicle characteristics
  - Traffic characteristics
  - Interaction characteristics
General approach

**Domain**
- Safety critical events
- Functionality
- Regulatory/standards conformity

**Scenario**
- Generate range of test conditions from
  - Accident data
  - Normal driving data
  - Other

**Simulation**
- Develop simulation environment
- Introduce stereotype scenarios
- Examine risks with parametric variation

**Physical tests**
- Simple alternative to simulation
- Convinces users

**Acceptance criteria**
- Pass/fail
- How to measure
Validation methodology

**Goal:** Enable virtual testing of automated driving systems in representative scenarios and environments

### Real-world scenarios
- Crash Data Analysis
  - Attribute Grouping into Level 1 and 2
  - Data Processing & Attribute Selection
  - Historical Crash Data

### Clustering
- Level 1
  - Association Rule Mining
    - Level 2
    - Hypotheses of criticalities
      - e.g., poor visibility

### Evaluation criteria
- Test Objectives and Research Questions
  - EXAMPLE: Evaluate the influence of poor visibility and limited sight distance on the safety performance of in-vehicle collision avoidance systems for various junction scenarios.

### Simulation parameters
- Monte Carlo Sampling
  - Probability distributions

### Sub-microscopic Simulation
- Road Environment Models
- Vehicle and Sensor Models
- Driving Behaviour Models
- Safety indicators calculation

### Simulated environment
Simulating CAV in traffic

• Predicting impact of ADAS and automation on safety, environment and mobility at individual and societal level
To reduce casualties we need new systems that improve VRU safety in towns and car/PTW safety on rural roads.

Ensure that mature injury mitigation technologies are integrated with new crash prevention systems to maximise safety.

Conduct realistic real-world demonstrations in controlled environments and the public roads and extensive virtual verification of operation.

Monitor the roll-out of autonomous systems to measure the real-world effect.
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