9. Microscopic Traffic Modeling
Traffic model classification (1)

- **Static**
  - Models average steady-state traffic situation

- **Dynamic**
  - Models *changes over time* of the traffic situation
Traffic model classification (2)

• Different levels of detail in simulation models:
  – Macroscopic:
    • Like water flowing through a pipe
  – Mesoscopic
    • Individual vehicles with aggregate behaviour
  – Microscopic
    • Individual vehicles with detailed behaviour
Traffic model classification (3)

• Other dimensions:
  – **Stochastic or Deterministic**:
    • **stochastic** modelling captures variation in e.g. reaction time, arrival processes, route choice. **But** every simulation run results in different outcome, so you need to **replicate simulation runs**
  – **Time-stepped or event-based**:
    • **Time stepped**: the model calculates the changes in the system for finite steps (e.g. 1 second)
    • **event based**: the model calculates changes in the system when something 'happens' (events)
Introduction to micro-simulation

• “A numerical technique for conducting experiments on a digital computer, which may... involve mathematical models that describe the behaviour of a transportation system over extended periods of time.”
Keywords:

- **System**: the real-world process to imitate;
- **Model**: the set of assumptions, in the form of mathematical or logical relationships, put forward to help understand how the corresponding system behaves;
- **Entities**: people or vehicles that act in the system;
- **Time**: an explicit element of the system.
Traffic micro-simulation entities

- Driver and vehicle characteristics.
  - Physical size: length and width
  - Mechanical capacity: maximum acceleration or deceleration
  - Driving behaviour: desired speed, reaction time, gap acceptance, aggressiveness, etc.
Traffic micro-simulation models

- Car-following model
- Lane-changing model
- Gap-acceptance model
- Lane-choice model
- Models of intersection controls
Microscopic models?

Lateral:
- lane-changing
- others, such as behaviour at discontinuities

Longitudinal:
- choosing free speed
- interacting with other vehicles and obstacles
Car-following models

• Models of individual vehicle following behaviour
  – In a single stream of traffic (lane disciplined)
  – No overtaking

• Three main types:
  – Safety-distance model
  – “Action-points”: different rules for different driving states
  – Psycho-physical:
    Acceleration=Stimulus x Sensitivity
Gap-acceptance models

• Models of individual drivers’ choice of safety gaps to **merge** into or to cross other traffic streams

• Two elements:
  – Gaps acceptable to drivers
  – Gaps available to the driver
Lane-changing models

- Models of individual drivers’ ability and propensity to change lanes
- Lane-changing objectives, e.g.
  - To overtake a slower moving vehicle
  - To bypass an obstacle
  - To move off/into a reserved bus lane
  - To get-in-lane for next junction turning
  - To give-way to merging traffic
- Decision-making behaviour:
  - Is it possible to change lane? (physically & safely)
  - Is it necessary to change lane? (for junction turning?)
Lane-choice models

- Selection of the lateral position in entering or traversing a link.

- Pre-specified, or

- Instantaneous **choice** made in response to traffic condition and destination
Models of intersection traffic control

- Signal controlled: fixed or responsive
- Priority giveaway
- Roundabout: partially signalised
- Motorway merge
- Stop-and-go
- Giveaway to oncoming traffic
Network representation

- Network topology
- Junction type and priority rules
- Link (major/minor, speed limits, ..)
- Lanes (turning restriction, access restriction)
- Signal plans (stages, phases, responsive rules)
Car-following models

Safety Distance model

Gipps Model
The Gipps car-following model

• Free flow model
  – Accelerate freely to desired speed

• Safety-distance model
  – Driver maintains a speed \( v \) which will just allow him to stop in emergency without hitting the obstacle at distance \( S \) ahead
• Free flow model

This model states that the maximum speed to which a vehicle (n) can accelerate in free flow condition during a time period (t, t+T)

\[
V_a (n, t + T) = V(n, t) + 2.5a(n)T \left( 1 - \frac{V(n, t)}{V^*(n)} \right) \sqrt{0.025 + \frac{V(n, t)}{V^*(n)}}
\]

where:

- V(n,t) is the speed of vehicle n at time t;
- V*(n) is the desired speed of the vehicle (n) for current section;
- a(n) is the maximum acceleration for vehicle n;
- T is the reaction time = updating interval = simulation step.

- Free flow:
• Safety-distance model

the other hand, the maximum speed that the same vehicle \( n \) can reach during the same time interval \( (t, t+T) \) according to its own characteristics and the limitations imposed by the presence of the leader vehicle is:

\[
V_b(n, t + T) = d(n)T + \sqrt{d(n)^2 T^2 - d(n) \left[ 2\left(x(n-1, t) - s(n-1) - x(n, t)\right) - V(n, t)T - \frac{V(n-1, t)^2}{d'(n-1)} \right]}
\]

where:
- \( d(n) < 0 \) is the maximum deceleration desired by vehicle \( n \);
- \( x(n,t) \) is position of vehicle \( n \) at time \( t \);
- \( x(n-1,t) \) is position of preceding vehicle \( (n-1) \) at time \( t \);
- \( s(n-1) \) is the effective length of vehicle \( (n-1) \);
- \( d'(n-1) \) is an estimation of vehicle \( (n-1) \) desired deceleration.

- Safety-distance:
• Desired speed

• Finding the desired speed of the vehicle \((n) \ (\_V^*(n))\)

\[ (\_V^*(n)) = \min (V(\text{sect}), V(\text{max})) \]

Where:
- \(V(\text{sect}) = \text{section speed limit}\)
- \(V(\text{max}) = \text{maximum vehicle speed}\)
• The modeled speed

In any case, the definitive speed for vehicle \( n \) during time interval \( (t, t+T) \) is the minimum of those previously defined speeds:

\[
V(n, t + T) = \min \left\{ V_a(n, t + T), V_b(n, t + T) \right\}
\]

Then, the position of vehicle \( n \) inside the current lane is updated taking this speed into the movement equation:

\[
x(n, t + T) = x(n, t) + V(n, t + T)T
\]
Psycho-physical:

Stimulus - response models
Stimulus – response models

Stimulus response model:

- Acceleration \( a_f \)
- Speed difference \( \Delta v \)
- Distance between cars \( \Delta x \)
- Speed of the following car \( v_f \)
Stimulus Response models

Gazis-Herman-Rothery (GHR) model

<table>
<thead>
<tr>
<th>Root models</th>
<th>( a_f(t+T_r) = )</th>
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</thead>
<tbody>
<tr>
<td>Chandler, Herman and Montroll</td>
<td>( c_1 \Delta v(t) )</td>
</tr>
<tr>
<td>Gazis, Herman and Potts</td>
<td>( c_2 \frac{\Delta v(t)}{\Delta x(t)} )</td>
</tr>
<tr>
<td>Edie</td>
<td>( c_3 v_f(t+T_r) \frac{\Delta v(t)}{\Delta x(t)} )</td>
</tr>
</tbody>
</table>

\[ c * v_n^m(t) * \frac{\Delta v(t-T_r)}{\Delta x^l(t-T_r)} \]