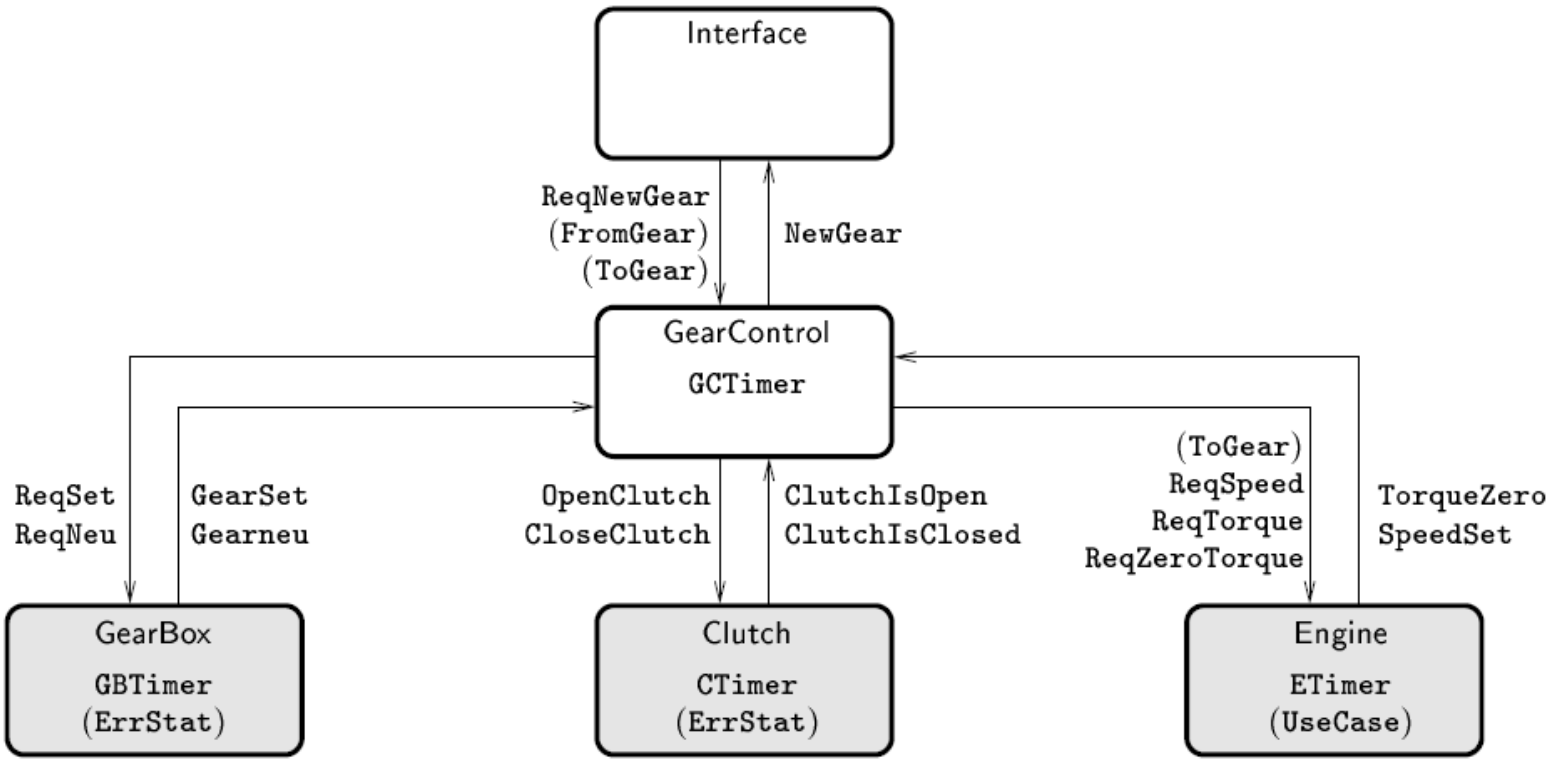
Gear Controller

Formal Design and Analysis of a Gear Controller. M. Lindahl, P. Pettersson, W. Yi.

- component in the real-time embedded system that operates in a modern vehicle (specifically Mecel AB)
- the gear-requests from the driver are delivered over a communication network to the gear controller
- the controller implements the actual gear change by actuating the lower level components of the system, such as the clutch, the engine and the gear-box

Interface

- receives service requests, keeps information about the current status
- used by:
  - the driver using the gear stick
  - dedicated component implementing the gear change algorithm


Interface
ReqNewGear
(FromGear)
(ToGear)
NewGear
GearControl
GCTimer
ReqSet
ReqNeu
GearSet
Gearneu
OpenClutch
CloseClutch
ClutchIsOpen
ClutchIsClosed
(ToGear)
ReqSpeed
ReqTorque
ReqZeroTorque
TorqueZero
SpeedSet
GearBox
GBTimer
(ErrStat)
Clutch
CTimer
(ErrStat)
Engine
ETimer
(UseCase)

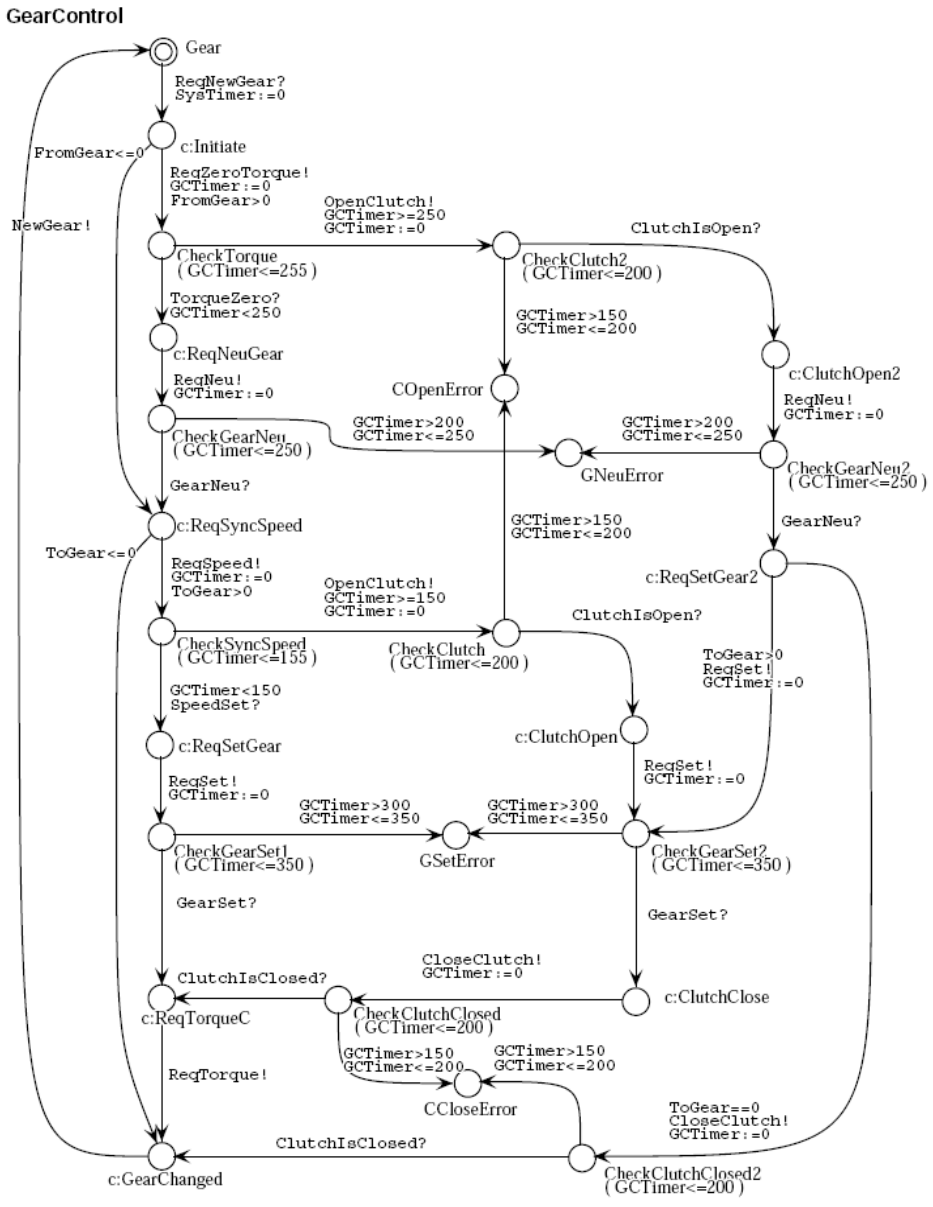
Functionality of the Controller

- gear change performed in five steps:
  1. accomplish zero torque
  2. release the current gear
  3. achieve synchronous speed
  4. set the new gear
  5. increase the engine torque back to previous level
- under difficult driving conditions: zero torque or synchronous speed not possible; then use the clutch

Timing Parameters

- setting/releasing of a gear by electrically controlled gear-box
- timeout for reaching the zero torque
- timeout for reaching synchronous speed
- time needed for opening/closing the clutch

Gear Controller



Requirements

- performance: a gear shift should be completed within 1.5 seconds, ...
- safety: controller detects and report errors if and only if clutch is not opened (closed) in time, ...
- functionality: it is possible to use all gears
- predictability: strict synchronization between components, e.g., when regulating torque, clutch should be closed, ...

$$\text{GearControl@Initiate} \rightsquigarrow_{\leq 1500} ((\texttt{ErrStat} = 0) \Rightarrow \text{GearControl@GearChanged})$$

$$\text{GearControl@Initiate} \rightsquigarrow_{\leq 1000} ((\texttt{ErrStat} = 0 \wedge \texttt{UseCase} = 0) \Rightarrow \text{GearControl@GearChanged})$$

$$\text{Clutch@ErrorClose} \rightsquigarrow_{\leq 200} \text{GearControl@CCloseError}$$

$$\text{Clutch@ErrorOpen} \rightsquigarrow_{\leq 200} \text{GearControl@COpenError}$$

$$\text{GearBox@ErrorIdle} \rightsquigarrow_{\leq 350} \text{GearControl@GSetError}$$

$$\text{GearBox@ErrorNeu} \rightsquigarrow_{\leq 200} \text{GearControl@GNeuError}$$

$$Inv (\text{GearControl@CCloseError} \Rightarrow \text{Clutch@ErrorClose})$$

$$Inv (\text{GearControl@COpenError} \Rightarrow \text{Clutch@ErrorOpen})$$

$$Inv (\text{GearControl@GSetError} \Rightarrow \text{GearBox@ErrorIdle})$$

$$Inv (\text{GearControl@GNeuError} \Rightarrow \text{GearBox@ErrorNeu})$$

$$Inv (\text{Engine@ErrorSpeed} \Rightarrow \texttt{ErrStat} \neq 0)$$

$$Inv (\text{Engine@Torque} \Rightarrow \text{Clutch@Closed})$$

$$\bigwedge_{i \in \{R,N,1,\ldots,5\}} Poss (\text{Gear@Gear}_i)$$

$$\bigwedge_{i \in \{R,1,\ldots,5\}} Inv ((\text{GearControl@Gear} \wedge \text{Gear@Gear}_i) \Rightarrow \text{Engine@Torque})$$