01

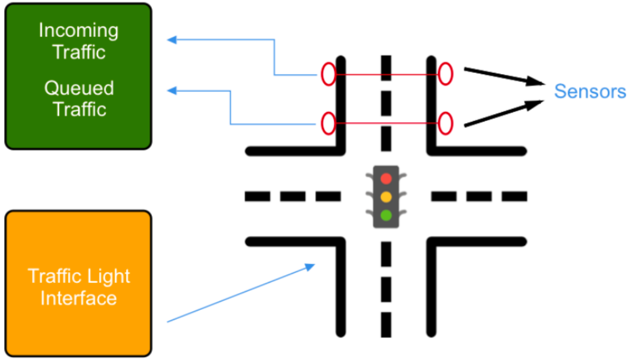
理论准备

模型简化

单行道

即将通行车辆(OncomingCar)：自南向北行驶

等待车辆(WaitingCar)：自东向西行驶



确定模糊控制器结构

选用两输入单输出模糊控制器

输入：即将通过的车辆(oncoming)

等待的车辆(waiting)

输出：绿灯时间

定义输入、输出模糊集

将等待车辆分为5个模糊集：Minimal(等待车辆很少)，Light (等待车辆少)，Average (等待车辆中等)，Heavy (等待车辆多)，Standstill (等待车辆很多)

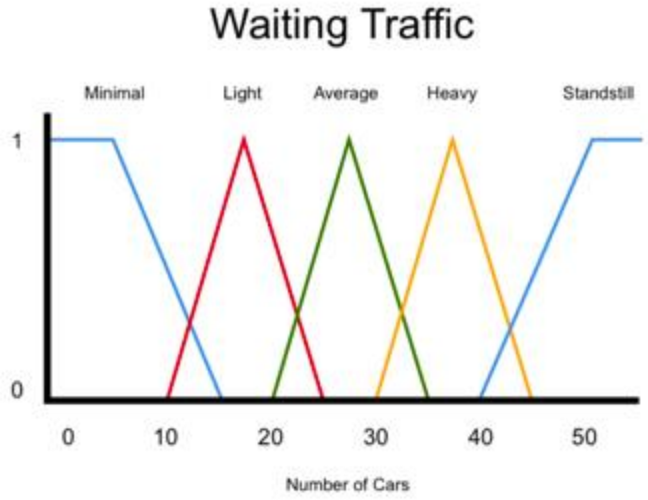
将即将通过车辆分为5个模糊集：Minimal(即将通过车辆很少)，Light (即将通过车辆少)，Average (即将通过车辆中等)，Heavy (即将通过车辆多)，Excess (即将通过车辆很多)

将绿灯时间分为3个模糊集：Short(短)，Medium(中等)，Long(长)

定义隶属度函数

选用如下隶属度函数

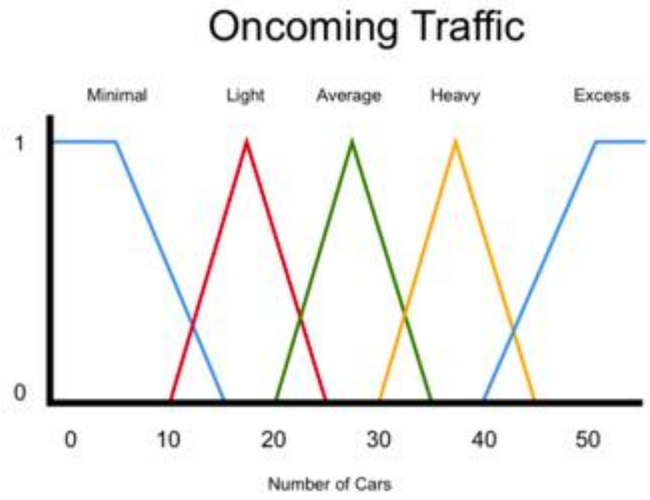
$$\mu_{等待车辆}=\begin{cases}\mu_{Minimal}(x)=\begin{cases}1 & 0\le x\le 7.5\\ \dfrac{2(15-x)}{15} & 7.5\le x\le 15\end{cases}\\ \mu_{Light}(x)=\begin{cases}\dfrac{2(x-10)}{15} & 10\le x\le 17.5\\ \dfrac{2(25-x)}{15} & 17.5\le x\le 25\end{cases}\\ \mu_{Average}(x)=\begin{cases}\dfrac{2(x-20)}{15} & 20\le x\le 27.5\\ \dfrac{2(35-x)}{15} & 27.5\le x\le 35\end{cases}\\ \mu_{Heavy}(x)=\begin{cases}\dfrac{2(x-30)}{15} & 30\le x\le 37.5\\ \dfrac{2(45-x)}{15} & 37.5\le x\le 45\end{cases}\\ \mu_{Excess}(x)=\begin{cases}\dfrac{x-40}{10} & 40\le x\le 50\\ 1 & x\ge 50\end{cases}\end{cases}$$



定义隶属度函数

选用如下隶属度函数

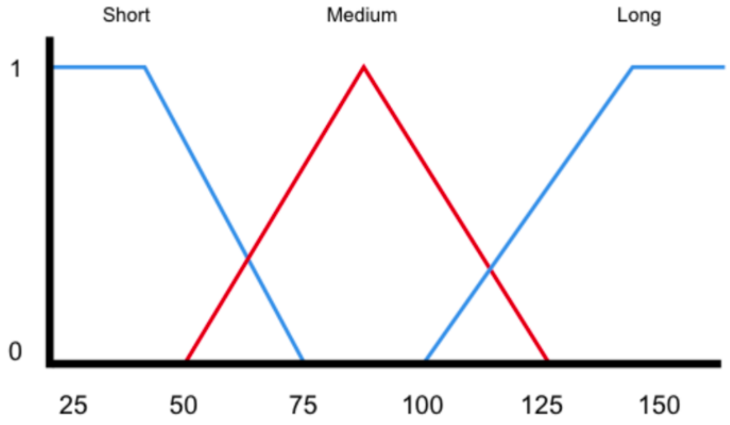
$$
\mu_{\text{[illegible]}}=\begin{cases}
\mu_{Minimal}(y)=\begin{cases}1 & 0\le y\le 7.5\\ \dfrac{2(15-y)}{15} & 7.5\le y\le 15\end{cases}\\[2ex]
\mu_{Light}(y)=\begin{cases}\dfrac{2(y-10)}{15} & 10\le y\le 17.5\\ \dfrac{2(25-y)}{15} & 17.5\le y\le 25\end{cases}\\[2ex]
\mu_{Average}(y)=\begin{cases}\dfrac{2(y-20)}{15} & 20\le y\le 27.5\\ \dfrac{2(35-y)}{15} & 27.5\le y\le 35\end{cases}\\[2ex]
\mu_{Heavy}(y)=\begin{cases}\dfrac{2(y-30)}{15} & 30\le y\le 37.5\\ \dfrac{2(45-y)}{15} & 37.5\le y\le 45\end{cases}\\[2ex]
\mu_{Excess}(y)=\begin{cases}\dfrac{y-40}{10} & 40\le y\le 50\\ 1 & y\ge 50\end{cases}
\end{cases}
$$



定义隶属度函数

选用如下隶属度函数

$$\mu_{绿灯时间}=\begin{cases}\mu_{Short}(z)=\begin{cases}1 & 25\le z\le 45\\ \dfrac{75-z}{30} & 45\le z\le 75\end{cases}\\ \mu_{Medium}(z)=\begin{cases}\dfrac{2(z-50)}{75} & 50\le z\le 87.5\\ \dfrac{2(125-z)}{75} & 87.5\le z\le 125\end{cases}\\ \mu_{Long}(z)=\begin{cases}\dfrac{2(z-100)}{75} & 100\le z\le 150\\ 1 & z\ge 150\end{cases}\end{cases}$$



02

控制规则

建立模糊控制规则

根据日常生活经验设计模糊规则，模糊规则设计的标准为：“等待车辆越多，即将通行车辆越多，绿灯时间越长”；“等待车辆适中，即将通行适中，绿灯时间适中”；“等待车辆越少，即将通行车辆越少，绿灯时间越少”。

建立模糊控制表

	Minimal (Oncoming)	Light	Average	Heavy	Excess
Minimal(Waiting)	Short*	Short	Medium	Long	Long
Light	Short	Short	Medium	Medium	Long
Average	Short	Medium	Medium	Long	Long
Heavy	Medium	Medium	Long	Long	Long
Standstill	Medium	Long	Long	Long	Long

第*条规则为：“IF MINIMAL AND MINIMAL THEN SHORT”

03

模糊推理

规则匹配

假定测得的信息为：x_0(等待的车辆)=14， y_0(即将通过的车辆)=33，分别代入所属的隶属度函数中求隶属度为

$\mu_{Minimal}(14)=0.13$ $\mu_{Light}(14)=0.53$

$\mu_{Average}(33)=0.27$ $\mu_{Heavy}(33)=0.4$

通过上述4种隶属度，可得到4条相匹配的模糊规则。

规则匹配

	Minimal (Oncoming)	Light	Average (0.27)	Heavy (0.4)	Excess
Minimal(Waiting) (0.13)	0	0	$\mu_{Medium}(z)$	$\mu_{Long}(z)$	0
Light (0.53)	0	0	$\mu_{Medium}(z)$	$\mu_{Medium}(z)$	0
Average	0	0	0	0	0
Heavy	0	0	0	0	0
Standstill	0	0	0	0	0

规则触发

01

IF x is Minimal And y is Average THEN z is Medium

02

IF x is Minimal And y is Heavy THEN z is Medium

03

IF x is Light And y is Average THEN z is Medium

04

IF x is Light And y is Heavy THEN z is Medium

规则前提推理

01

IF x is Minimal And y is Average THEN z is Medium

min(0.13,0.27)=0.13

02

IF x is Minimal And y is Heavy THEN z is Medium

min(0.13,0.4)=0.13

03

IF x is Light And y is Average THEN z is Medium

min(0.53,0.27)=0.27

04

IF x is Light And y is Heavy THEN z is Medium

min(0.53,0.4)=0.4

规则前提可信度

	Minimal (Oncoming)	Light	Average (0.27)	Heavy (0.4)	Excess
Minimal(Waiting) (0.13)	0	0	0.13	0.13	0
Light (0.53)	0	0	0.27	0.4	0
Average	0	0	0	0	0
Heavy	0	0	0	0	0
Standstill	0	0	0	0	0

规则总的可信度

	Minimal (Oncoming)	Light	Average (0.27)	Heavy (0.4)	Excess
Minimal (Waiting) (0.13)	0	0	$\min(0.13,\mu_{Medium}(z))$	$\min(0.13,\mu_{Long}(z))$	0
Light (0.53)	0	0	$\min(0.27,\mu_{Medium}(z))$	$\min(0.4,\mu_{Medium}(z))$	0
Average	0	0	0	0	0
Heavy	0	0	0	0	0
Standstill	0	0	0	0	0

模糊系统总的输出

模糊系统总的可信度为各条规则可信度推理结果的并集，即

$\mu(z)=\max\{\min(0.13,\mu_{Medium}(z))$，$\min(0.13,\mu_{Long}(z))$, $\min(0.27,\mu_{Medium}(z))$, $\min(0.4,\mu_{Medium}(z))\}$

$=\max\{\min(0.13,\mu_{Long}(z))$， $\min(0.4,\mu_{Medium}(z))\}$

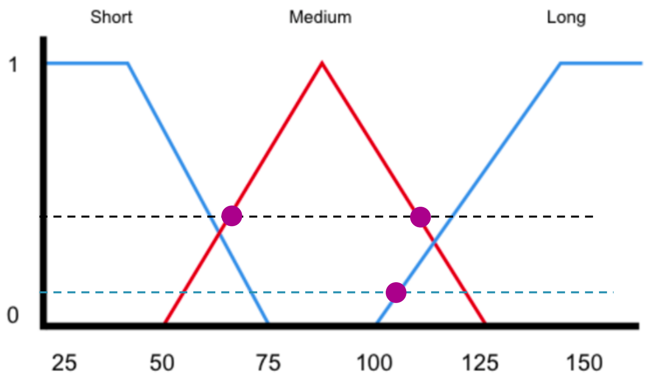
有2条规则被触发

反模糊化

模糊系统的总输出：2个规则推理结果的并集

反模糊化：加权平均法

$$\left.\begin{array}{l}\mu_L=\dfrac{2(z-100)}{75}=0.13 \quad z=106.5 \\ \left.\begin{array}{l}\mu_M=\dfrac{2(z-50)}{75}=0.4 \quad z=65 \\ \mu_M=\dfrac{2(125-z)}{75}=0.4 \quad z=110\end{array}\right\} \text{取大，} z=110\end{array}\right\} \text{平均值 } z=108.25$$



即在该条件下，绿灯时间为108.25s

04

程序仿真

考虑一个简单的四路交叉口并观察其状态图。这个四路交叉口由两条街道 Main 和 Side 组成。假设没有转弯车道，十字路口可以归结为四种不同的状态。