```
syms v_l v_m t(y_Q) r y_P y_Q x_c y_c x_P x_Q L l t2(y_Q)
assume(y_Q,'real')
assume(t(y_Q),'real')
assumeAlso(-20<y_Q<20)
d = abs((y_Q-y_P)*x_c+(x_Q-x_P)*y_c+(x_P-x_Q)*y_P-(y_P-y_Q)*x_P)/sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

d =

$$\frac{\left|y_c\left(x_P-x_Q\right)-y_P\left(x_P-x_Q\right)+x_P\left(y_P-y_Q\right)+x_c\left(y_P-y_Q\right)\right|}{\sqrt{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}}$$

```
l = 2*sqrt(r^2 - d^2)
```

l =

$$2\sqrt{r^2-\frac{\left|y_c\left(x_P-x_Q\right)-y_P\left(x_P-x_Q\right)+x_P\left(y_P-y_Q\right)+x_c\left(y_P-y_Q\right)\right|^2}{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}}$$

```
L = sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

L =

$$\sqrt{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}$$

```
t(y_Q) = l/v_l + (L-l)/v_m
```

t(y_Q) =

$$\frac{\sigma_1}{v_l}-\frac{\sigma_1-\sqrt{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}}{v_m}$$

where

$$\sigma_1 = 2\sqrt{r^2-\frac{\left|y_c\left(x_P-x_Q\right)-y_P\left(x_P-x_Q\right)+x_P\left(y_P-y_Q\right)+x_c\left(y_P-y_Q\right)\right|^2}{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}}$$

```
t2(y_Q) = L/v_m
```

t2(y_Q) =

$$\frac{\sqrt{\left(x_P-x_Q\right)^2+\left(y_P-y_Q\right)^2}}{v_m}$$

```
h(y_Q) = simplify(diff(t, y_Q, 1))
```

h(y_Q) =

$$-\frac{\frac{2y_P - 2y_Q}{2\sqrt{\sigma_3}} - \frac{\sigma_1}{\sigma_2}}{v_m} - \frac{\sigma_1}{v_l \sigma_2}$$

where

$$\sigma_1 = \frac{{\sigma_4}^2 \left(2y_P - 2y_Q\right)}{{\sigma_3}^2} - \frac{2\,\sigma_4 \operatorname{sign}\left(y_c \left(x_P - x_Q\right) - y_P \left(x_P - x_Q\right) + x_P \left(y_P - y_Q\right) + x_c \left(y_P - y_Q\right)\right) \left(x_P + x_c\right)}{\sigma_3}$$

$$\sigma_2 = \sqrt{r^2 - \frac{{\sigma_4}^2}{\sigma_3}}$$

$$\sigma_3 = \left(x_P - x_Q\right)^2 + \left(y_P - y_Q\right)^2$$

$$\sigma_4 = \left|y_c \left(x_P - x_Q\right) - y_P \left(x_P - x_Q\right) + x_P \left(y_P - y_Q\right) + x_c \left(y_P - y_Q\right)\right|$$

```
h2(y_Q) = simplify(diff(t2, y_Q, 1))
```

h2(y_Q) =

$$-\frac{y_P - y_Q}{v_m \sqrt{\left(x_P - x_Q\right)^2 + \left(y_P - y_Q\right)^2}}$$

```
x_P = 20
```

x_P = 20

```
y_P = 4.2
```

y_P = 4.2000

```
x_Q = -20
```

x_Q = -20

```
r = 6.3
```

r = 6.3000

```
x_c = 0.25
```

x_c = 0.2500

```
y_c = 9.875
```

y_c = 9.8750

```
v_l = 1450
```

```
v_l = 1450
```

```
v_m = 1580
```

```
v_m = 1580
```

```
d = abs((y_Q-y_P)*x_c+(x_Q-x_P)*y_c+(x_P-x_Q)*y_P-(y_P-y_Q)*x_P)/sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

```
d =
```

$$\frac{\left|\frac{81 y_Q}{4} - \frac{6241}{20}\right|}{\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}$$

```
l = 2*sqrt(r^2 - d^2)
```

```
l =
```

$$2 \sqrt{\frac{3969}{100} - \frac{\left|\frac{81 y_Q}{4} - \frac{6241}{20}\right|^2}{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}$$

```
L = sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

```
L =
```

$$\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}$$

```
t(y_Q) = l/v_l + (L-l)/v_m
```

```
t(y_Q) =
```

$$\frac{13 \sqrt{\frac{3969}{100} - \frac{\left|\frac{81 y_Q}{4} - \frac{6241}{20}\right|^2}{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}}{114550} + \frac{\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}{1580}$$

```
h(y_Q) = simplify(diff(t, y_Q, 1))
```

```
h(y_Q) =
```

$$\frac{5 y_Q - 21}{1580 \sqrt{25 {y_Q}^2 - 210 y_Q + 40441}} - \frac{65 \left(459675 {y_Q}^2 + 56595830 y_Q - 981291153\right)}{4582 \left(25 {y_Q}^2 - 210 y_Q + 40441\right)^{3/2} \sqrt{-3703725 {y_Q}^2 + 123046290}}$$

```
t2(y_Q) = L/v_m
```

t2(y_Q) =

$$\frac{\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}{1580}$$

```
h2(y_Q) = simplify(diff(t2, y_Q, 1))
```

h2(y_Q) =

$$\frac{5y_Q - 21}{7900\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}$$

```
y_Q_cont = solve(d==r, y_Q, 'Real',true)
```

y_Q_cont =

$$\frac{151909}{9145} - \frac{1400\sqrt{25765}}{16461}$$

```
y_Q_cont2 = double(y_Q_cont)
```

y_Q_cont2 = 2.9594

```
t_all = piecewise(-20<y_Q<=y_Q_cont2, t2(y_Q), y_Q_cont2<y_Q<20, t(y_Q))
```

t_all =

$$\begin{cases} \frac{\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}{1580} & \text{if } y_Q \le \frac{3332042974138543}{1125899906842624} \\ 13\sqrt{\frac{3969}{100} - \frac{\left|\frac{81y_Q}{4} - \frac{6241}{20}\right|^2}{\left(y_Q - \frac{21}{5}\right)^2 + 1600}} + \frac{\sqrt{\left(y_Q - \frac{21}{5}\right)^2 + 1600}}{1580} & \text{if } \frac{3332042974138543}{1125899906842624} < y_Q \end{cases}$$

```
fplot(t_all,[-20, 20],'Color','red')
xlabel('y_Q[mm]')
ylabel('arrival time[s]')
g_P7 = matlabFunction(t)
```

g_P7 = 値をもつ function_handle:

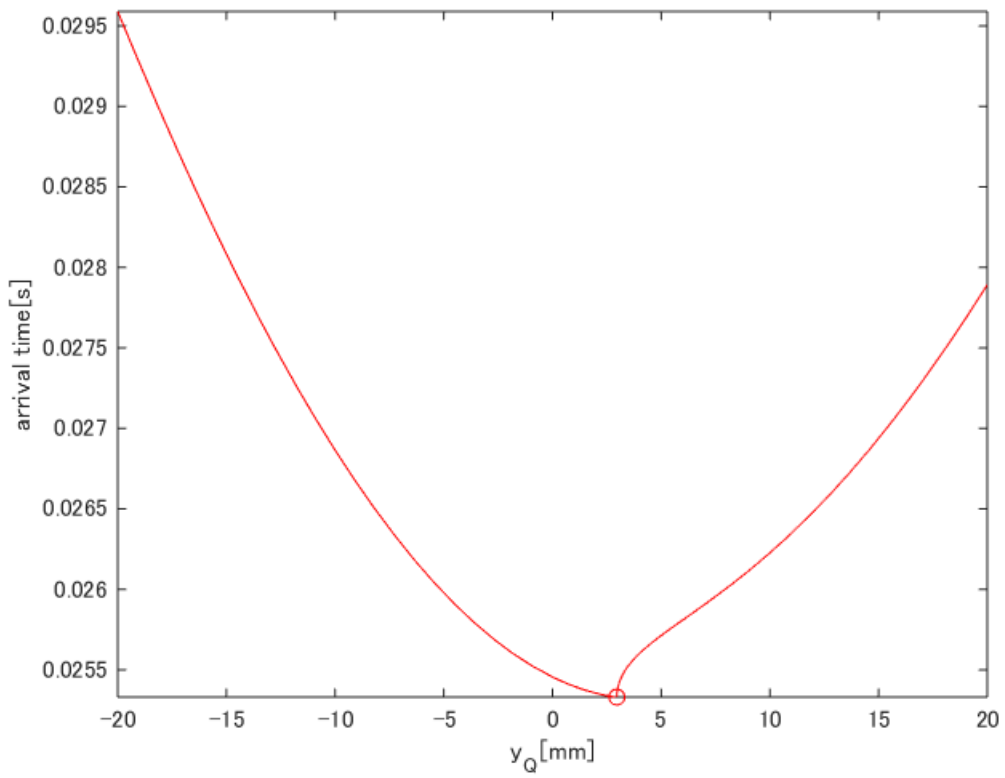
```
    @(y_Q)sqrt(-abs(y_Q.*(8.1e1./4.0)-3.1205e2).^2./((y_Q-2.1e1./5.0).^2+1.6e3)+3.969e1).*1.13487560017
```

```
y_Q0_P7 = fminbnd(g_P7,y_Q_cont2,20)
```

y_Q0_P7 = 2.9595

```
hold on
```

```
scatter(y_Q0_P7, g_P7(y_Q0_P7),'red')
```




```
% exportfig('\\Azlab-fs01\東研究室\個人work\竹内(ひ)\result\2018_05_17_handValidationLipidModel\2018
```

```
y_P = 8.3
```

```
y_P = 8.3000
```

```
d = abs((y_Q-y_P)*x_c+(x_Q-x_P)*y_c+(x_P-x_Q)*y_P-(y_P-y_Q)*x_P)/sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

```
d =
```

$$\frac{\left|\frac{81 y_Q}{4} - \frac{9243}{40}\right|}{\sqrt{\left(y_Q - \frac{83}{10}\right)^2 + 1600}}$$

```
l = 2*sqrt(r^2 - d^2)
```

```
l =
```

$$2\sqrt{\frac{3969}{100}-\frac{\left|\frac{81y_Q}{4}-\frac{9243}{40}\right|^2}{\left(y_Q-\frac{83}{10}\right)^2+1600}}$$

```
L = sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

L =

$$\sqrt{\left(y_Q-\frac{83}{10}\right)^2+1600}$$

```
t(y_Q) = l/v_l + (L-l)/v_m
```

t(y_Q) =

$$\frac{13\sqrt{\frac{3969}{100}-\frac{\left|\frac{81y_Q}{4}-\frac{9243}{40}\right|^2}{\left(y_Q-\frac{83}{10}\right)^2+1600}}}{114550}+\frac{\sqrt{\left(y_Q-\frac{83}{10}\right)^2+1600}}{1580}$$

```
h(y_Q) = simplify(diff(t, y_Q, 1))
```

h(y_Q) =

$$\frac{2y_Q-\frac{83}{5}}{316\sqrt{100y_Q^2-1660y_Q+166889}}-\frac{1170\left(6300y_Q^2+3115820y_Q-36375313\right)}{2291\left(100y_Q^2-1660y_Q+166889\right)^{3/2}\sqrt{-182900y_Q^2+42961}}$$

```
t2(y_Q) = L/v_m
```

t2(y_Q) =

$$\frac{\sqrt{\left(y_Q-\frac{83}{10}\right)^2+1600}}{1580}$$

```
h2(y_Q) = simplify(diff(t2, y_Q, 1))
```

h2(y_Q) =

$$\frac{2y_Q-\frac{83}{5}}{3160\sqrt{\left(y_Q-\frac{83}{10}\right)^2+1600}}$$

```
y_Q_cont = solve(d==r, y_Q, 'Real',true)
```

y_Q_cont =

$$\frac{214807}{18290} - \frac{280\sqrt{7365}}{1829}$$

```
y_Q_cont2 = double(y_Q_cont)
```

```
y_Q_cont2 = -1.3935
```

```
t_all = piecewise(-20<y_Q<=y_Q_cont2, t2(y_Q), y_Q_cont2<y_Q<20, t(y_Q))
```

```
t_all =
```

$$\begin{cases} \dfrac{\sqrt{\left(y_Q - \frac{83}{10}\right)^2 + 1600}}{1580} & \text{if } y_Q \le -\dfrac{392246213069007}{281474976710656} \\ 13\sqrt{\dfrac{3969}{100} - \dfrac{\left|\frac{81 y_Q}{4} - \frac{9243}{40}\right|^2}{\left(y_Q - \frac{83}{10}\right)^2 + 1600}} \Big/ 114550 + \dfrac{\sqrt{\left(y_Q - \frac{83}{10}\right)^2 + 1600}}{1580} & \text{if } -\dfrac{392246213069007}{281474976710656} < y_Q \end{cases}$$

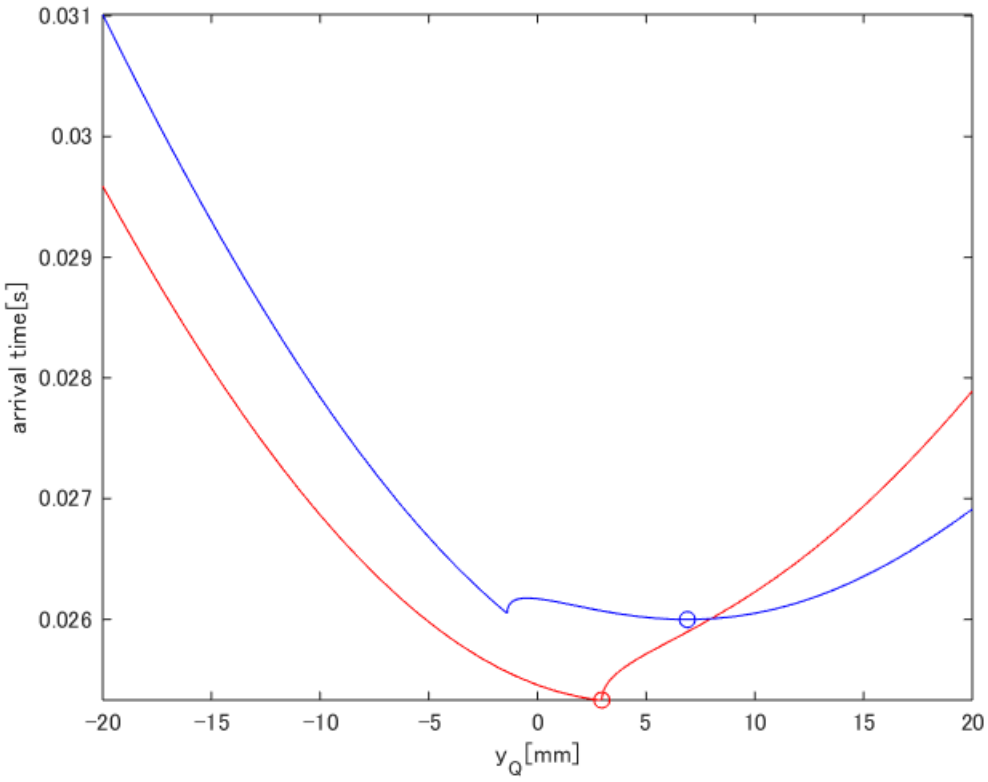
```
fplot(t_all,[-20, 20],'Color','blue')
xlabel('y_Q[mm]')
ylabel('arrival time[s]')
g_P8 = matlabFunction(t)
```

```
g_P8 = 値をもつ function_handle:
    @(y_Q)sqrt(-abs(y_Q.*(8.1e1./4.0)-2.31075e2).^2./((y_Q-8.3e1./1.0e1).^2+1.6e3)+3.969e1).*1.13487560
```

```
y_Q0_P8 = fminbnd(g_P8,y_Q_cont2,20)
```

```
y_Q0_P8 = 6.8911
```

```
scatter(y_Q0_P8, g_P8(y_Q0_P8),'blue')
```




```
% exportfig('\\Azlab-fs01\東研究室\個人work\竹内(ひ)\result\2018_05_17_handValidationLipidModel\2018
```

```
y_P = 12.3
```

```
y_P = 12.3000
```

```
d = abs((y_Q-y_P)*x_c+(x_Q-x_P)*y_c+(x_P-x_Q)*y_P-(y_P-y_Q)*x_P)/sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

```
d =
```

$$\frac{\left|\frac{81y_Q}{4}-\frac{6083}{40}\right|}{\sqrt{\left(y_Q-\frac{123}{10}\right)^2+1600}}$$

```
l = 2*sqrt(r^2 - d^2)
```

```
l =
```

$$2\sqrt{\frac{3969}{100}-\frac{\left|\frac{81y_Q}{4}-\frac{6083}{40}\right|^2}{\left(y_Q-\frac{123}{10}\right)^2+1600}}$$

```
L = sqrt((y_P-y_Q)^2+(x_Q-x_P)^2)
```

L =

$$\sqrt{\left(y_Q - \frac{123}{10}\right)^2 + 1600}$$

```
t(y_Q) = l/v_l + (L-l)/v_m
```

t(y_Q) =

$$\frac{13\sqrt{\frac{3969}{100} - \frac{\left|\frac{81y_Q}{4} - \frac{6083}{40}\right|^2}{\left(y_Q - \frac{123}{10}\right)^2 + 1600}}}{114550} + \frac{\sqrt{\left(y_Q - \frac{123}{10}\right)^2 + 1600}}{1580}$$

```
h(y_Q) = simplify(diff(t, y_Q, 1))
```

h(y_Q) =

$$\frac{2y_Q - \frac{123}{5}}{316\sqrt{100{y_Q}^2 - 2460y_Q + 175129}} + \frac{130\left(785700{y_Q}^2 - 278004620y_Q + 204346\right.}{2291\left(100{y_Q}^2 - 2460y_Q + 175129\right)^{3/2}\sqrt{-14814900{y_Q}^2 + 207}}$$

```
t2(y_Q) = L/v_m
```

t2(y_Q) =

$$\frac{\sqrt{\left(y_Q - \frac{123}{10}\right)^2 + 1600}}{1580}$$

```
h2(y_Q) = simplify(diff(t2, y_Q, 1))
```

h2(y_Q) =

$$\frac{2y_Q - \frac{123}{5}}{3160\sqrt{\left(y_Q - \frac{123}{10}\right)^2 + 1600}}$$

```
y_Q_cont = solve(d==r, y_Q, 'Real',true)
```

y_Q_cont =

$$\frac{127967}{18290} - \frac{280\sqrt{602005}}{16461}$$

```
y_Q_cont2 = double(y_Q_cont)
```

y_Q_cont2 = -6.2013

```
t_all = piecewise(-20<y_Q<=y_Q_cont2, t2(y_Q), y_Q_cont2<y_Q<20, t(y_Q))
```

```
t_all =
```

$$\begin{cases} \dfrac{\sqrt{\left(y_Q-\frac{123}{10}\right)^2+1600}}{1580} & \text{if } y_Q \le -\dfrac{6981991656581891}{1125899906842624} \\ \dfrac{13\sqrt{\frac{3969}{100}-\frac{\left|\frac{81y_Q}{4}-\frac{6083}{40}\right|^2}{\left(y_Q-\frac{123}{10}\right)^2+1600}}}{114550}+\dfrac{\sqrt{\left(y_Q-\frac{123}{10}\right)^2+1600}}{1580} & \text{if } -\dfrac{6981991656581891}{1125899906842624} < y_Q \end{cases}$$

```
fplot(t_all,[-20, 20],'Color','green')
xlabel('y_Q[mm]')
ylabel('arrival time[s]')
g_P9 = matlabFunction(t)
```

```
g_P9 = 値をもつ function_handle:
    @(y_Q)sqrt(-abs(y_Q.*(8.1e1./4.0)-1.52075e2).^2./((y_Q-1.23e2./1.0e1).^2+1.6e3)+3.969e1).*1.1348756
```

```
y_Q0_P9 = fminbnd(g_P9,y_Q_cont2,20)
```

```
y_Q0_P9 = 14.9841
```

```
scatter(y_Q0_P9, g_P9(y_Q0_P9),'green')
hold off
legend('P7','min(P7)','P8','min(P8)','P9','min(P9)')
exportfig('\\Azlab-fs01\東研究室\個人work\竹内(ひ)\result\2018_05_17_handValidationLipidModel\2018_0
```