

Appendix I

I Distance-dependence of IR temperature detection

I.1 Data of the worst-case experiment

The following worst-case temperature data are used:

x [cm]	T [°C]
5	50.00
10	45.00
20	41.50
30	36.50
40	29.75
50	27.00
60	26.00
70	24.75
80	24.25
90	24.00
100	24.00

The ambient temperature is $T_{\text{amb}} = 23.5^\circ\text{C}$.

I.2 Regression exponential function

The distance dependence is now modeled as an exponential function of the form

$$T(x) = T_{\text{amb}} + Ae^{Bx} \iff T(x) - T_{\text{amb}} = Ae^{Bx}.$$

Linearizing the model gives

$$\ln(T(x) - T_{\text{amb}}) = \ln A + Bx.$$

Defining

$$Y_i = \ln(T_i - T_{\text{amb}}),$$

the regression becomes linear:

$$Y_i = \alpha + Bx_i, \quad \text{with} \quad \alpha = \ln A.$$

The slope B is then given by

$$B = \frac{\sum_i x_i Y_i - \frac{1}{n} (\sum_i x_i) (\sum_i Y_i)}{\sum_i x_i^2 - \frac{1}{n} (\sum_i x_i)^2},$$

and the intercept α by

$$\alpha = \bar{Y} - B\bar{x},$$

where

$$\bar{x} = \frac{\sum_i x_i}{n}, \quad \bar{Y} = \frac{\sum_i Y_i}{n}.$$

Finally,

$$A = e^\alpha.$$

Using the data in section 1.1, the fitted parameters are

$$A = 38.72, \quad B = -0.04661,$$

which gives

$$T(x) = 23.5 + 38.72e^{-0.04661x}.$$

I.3 Final step function

To impose a conservative lower-bound behavior, the final model is defined piecewise as

$$T(x) = \begin{cases} 30, & \text{for } x \leq 38.28694, \\ 23.5 + 38.72e^{-0.04661x}, & \text{for } 38.28694 < x < 78.44575, \\ 24.5, & \text{for } x \geq 78.44575. \end{cases}$$

The first transition point was chosen such that

$$23.5 + 38.72e^{-0.04661x} = 30$$

at

$$x = 38.28694 \text{ cm},$$

and the second transition point such that

$$23.5 + 38.72e^{-0.04661x} = 24.5$$

at

$$x = 78.44575 \text{ cm}.$$

Thus, the piecewise function is continuous at both transition points.

I.4 Graphic

