2. DESCRIPTION OF THE CASES

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ABSTRACT

In this chapter definitions are given and the five cases are presented as they were described in the instructions of the system identification competition. Furthermore the authors have added some additional comments with every case, to provide some background information why the particular cases have been selected for the competition. The statistics of each data set are given at the end of the chapter.

2.1 DEFINITIONS

2.1.1 Building-physical definitions

R is the *thermal resistance* (surface-to-surface) defined as the difference between the two surface temperatures in steady state divided by the density of heat flow rate, in $°Cm^2/W$

C_i is the *internal thermal capacity* per unit area of the wall defined as the amount of heat that goes into the wall per m^2 as the result of a change from one steady state situation to another by increasing the internal surface temperature with 1°*C*, in $Wh/°Cm^2$

C_e is the *external thermal capacity* per unit area of the wall defined as the amount of heat which goes into the wall per m^2 as the result of a change from one steady state situation to another by increasing the external surface temperature with 1°*C*, in $Wh/°Cm^2$

C is the *thermal capacity* per unit area of the wall defined as the sum $C_i + C_e$, in $Wh/°Cm^2$

2.1.2 Mathematical definitions

The wall may be considered as a constant parameter linear system with the density of heat flow rate at the internal surface as the output variable and the two surface temperatures as input variables. In continuous time the relationship may be written as

$$q_i(t) = \int_0^\infty w_1(t) q_i(t-t)\,dt - \int_0^\infty w_2(t) q_e(t-t)\,dt \qquad (2.1)$$

where $w_1(t)$ and $w_2(t)$ are weighting functions.

The thermal resistance R may defined by:

$$\frac{1}{R} = \int_0^{\infty} w_1(t)dt = \int_0^{\infty} w_2(t)dt \tag{2.2}$$

In the case of a 'symmetric' wall, the heat flow density at the external surface may be written as

$$q_e(t) = \int_0^{\infty} w_2(t)q_i(t-t)dt - \int_0^{\infty} w_1(t)q_e(t-t)dt \tag{2.3}$$

The thermal capacity C may in this case be defined by the following equation

$$C = C_i + C_e = 2\int_{t=0}^{\infty}\int_{t=0}^{t}\left(w_1(t) - w_2(t)\right)tdt \tag{2.4}$$

2.1.3 Comments

a. Case 1 (homogenous wall) and Case 2 (three-layer symmetric wall) are concerned with estimation of R and C defined by (2) and (4). In particular, equation (3) is valid. Moreover, the internal capacity C_i is equal to the external thermal capacity C_e in these two cases.

b. Case 3 is concerned with estimation of five specially defined parameters (H_1,H_2, H_3, G_1 and G_2) of a lumped parameter system that are not given building physical and mathematical definitions above.

c. Case 4 is concerned with predictions of the heat flow density (1) at the internal surface of a two-layer wall with thermal resistance R defined by (2). The thermal capacity C is not mathematically defined by (4) in this case.

d. Case 5 is concerned with predictions of the heat flow density (1) at the internal surface of a homogenous wall described by the thermal parameters R and C defined by (2) and (4), respectively.

2.2 THE 5 CASES

2.2.1. Case 1

Point estimation of R and C of a homogeneous wall and time of a sensor failure

Given: Two data sets (called *Data11* and *Data12*) are given for a homogeneous wall with a high thermal mass and a high thermal resistance. The heat flow density is assumed to be the average of four heat flow sensors. The external and internal temperatures are assumed to be averages of four temperature sensors each. The data are corrupted by white noise.

Method for data generation: First noise-free frequency data were generated from the solution of the Fourier or heat conduction equation in the frequency domain. After transformation to the time domain noise was added to all three variables.

Data11 contains data for 56 days.
Data12 are identical to *Data11* to which have been added data for fourteen additional days. *Data12* contains data for 70 days. At some point of time after eight weeks, one of the temperature signals changes because of a failure of one of the sensors. This change lasts for the rest of the measurement period.

Sought : Estimates of R and C from *Data11* and time of sensor failure in *Data12* (minimum requirement is 3 values).
Optional : Estimates of the standard deviation (sR and sC) of the estimates R and C.

This case has been designed in such a way that the average method could be applied as well. A long data set containing 8 weeks of data with hourly observations is provided and was intended as a relative easy case. The difficult part is the assessment of the time of sensor failure.

2.2.2 Case 2

Estimation of R and C of a three-layer wall and estimation of the standard error of these estimates.

Given: Twenty data-sets (called *Data201* to *Data220)* for a symmetric three-layer wall (brick-insulation-brick). The heat flow density is assumed to be the average of several heat flow sensors. The external and internal temperatures are assumed to be averages of several temperature sensors each. The data are corrupted by white noise.

Method for data generation: First noise-free data were generated from the solution of the heat conduction equation using the theory of heat conduction through multi-layer walls. Then noise was added to all variables as in case 1. The twenty data-sets are the same except for twenty different realisations of the noise. Each set contains data for 25 days.

Sought : Twenty sets of estimates of R and C and estimates (sR and sC) of their standard deviations (minimum requirement is 80 values).

The aim of this case is to test the confidence interval of the estimates produced by the methods, which should be an important aspect to guarantee a good quality of the analysis result.

2.2.3 Case 3

Estimation of a true lumped parameter system

Given: Twenty data sets (called *Data301* to *Data320*) are given for a second order linear thermal network is specified, representing a wall component. The model is shown in the figure below. The data sets contain two temperatures each and one heat flow signal. The data are corrupted by white noise.

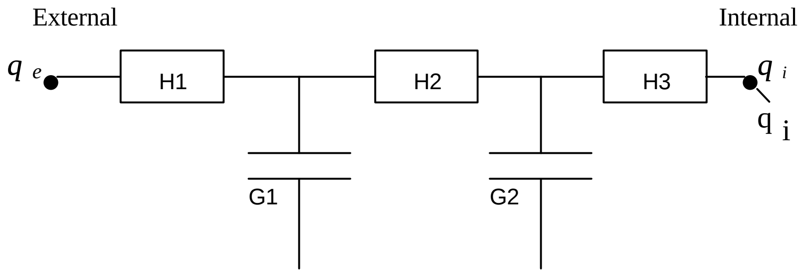

Figure 2.1. Second order model

Method for data generation: The data are generated from the network system shown in figure 2. Each set contains data for 30 days of hourly observations. A relatively high level of noise was added to the external temperature. A low noise level was added to the heat flow signal and no noise was added to the indoor temperature. The twenty data-sets are the same except for twenty different realisations of the noise.

Sought : Twenty sets of estimates of the mathematical parameters H1, H2, H3, G1 and G2 and estimates sH1, sH2, sH3, sG1 and sG2 of their standard deviation (required are 200 values).

This case was introduced to see if the methods are able to estimate the individual parameters of a thermal network and thus only applicable to these type of methods.

2.2.4 Case 4

Prediction of heat flow density through a two-layer wall

Given: Two data sets (called *Data41* and *Data42*) for a two-layer wall (a brick layer with an insulation layer put on the internal side of the wall). *Data41* (the estimation data set) consists of measurements of all three variables (two temperatures and one heat flow). *Data42* (the prediction data set) consists of measurements of only the internal and external temperatures which are a continuation of *Data41* temperature sequences.

The heat flow density is assumed to be the average of several heat flow sensors. The external and internal temperatures are assumed to be averages of several temperature sensors each. The data are corrupted by white noise. Each data set contains data for 70 days.

Method for data generation: The same as in Case 2.

Sought : Prediction of the heat flow density for *Data42*.
Optional : Estimates of R and C and estimates (sR and sC) of their standard deviation.

Case 4 is intended as a relative easy case for prediction. The data set is chosen to be long for this purpose and contain 10 weeks of hourly observations each.

2.2.5 Case 5

Prediction of heat flow density through a homogeneous layer for changed weather conditions

Given: Two data sets (called *Data51* and *Data52*) are created for a homogeneous wall. The first (estimation) data set consists of measurements of all three variables. The second (prediction) data set consists of measurements of only the internal and external temperatures which are a continuation of *Data51*. The overall weather conditions are not the same in *Data51* and *Data52*.

The heat flow density is assumed to be the average of several heat flow sensors. The external and internal temperatures are assumed to be averages of several temperature sensors each. The data are corrupted by white noise. Each data set contains data for 28 days.

Method for data generation: The same as in Case 1.

Sought : Prediction of the heat flow density for *Data52*.
Optional : Estimates of R and C and estimates (sR and sC) of their standard deviation.

In comparison to Case 4, a more difficult prediction case. The data set is much shorter, only 4 weeks and the external temperature is changing behaviour in the second part.

2.3 STATISTICS

Statistics of 'data11.txt'

	Te	Ti	qi
Max	28.440	28.050	6.5970
Average	17.829	22.950	0.5585
Min	4.410	16.690	-4.7190
Var	21.819	3.289	4.4221
Length	1344	1344	1344

Statistics of 'data12.txt'

	Te	Ti	qi
Max	28.440	28.050	7.7380
Average	16.736	22.585	0.5732
Min	4.410	16.690	-4.7190
Var	24.803	3.751	4.5305
Length	1680	1680	1680

All data2xx files are of length 600

Statistics of 'data201.txt'

	Te	Ti	qi
Max	19.860	25.450	52.4970
Average	10.521	20.955	3.4000
Min	2.430	17.230	-57.1420
Var	12.021	3.884	280.2929

Statistics of 'data202.txt'

	Te	Ti	qi
Max	20.110	25.560	52.2230
Average	10.546	20.973	3.4059
Min	2.980	16.980	-56.9930
Var	12.237	3.878	279.9995

Statistics of 'data203.txt'

	Te	Ti	qi
Max	19.480	25.280	52.2620
Average	10.515	20.959	3.4060
Min	2.440	17.110	-57.0310
Var	12.137	3.882	280.3781

Statistics of 'data204.txt'

	Te	Ti	qi
Max	20.520	25.510	52.3800
Average	10.548	20.970	3.3994
Min	2.590	17.210	-57.1840
Var	12.154	3.915	280.4188

Statistics of 'data205.txt'

	Te	Ti	qi
Max	19.860	25.320	52.2520
Average	10.539	20.957	3.4028
Min	2.740	17.060	-57.1700
Var	12.154	3.931	280.3197

Statistics of 'data206.txt'

	Te	Ti	qi
Max	20.010	25.330	52.3490
Average	10.523	20.957	3.4078
Min	3.070	16.960	-57.1550
Var	11.931	3.920	280.2299

Statistics of 'data207.txt'

	Te	Ti	qi
Max	20.360	25.380	52.4550
Average	10.516	20.960	3.4095
Min	3.310	16.930	-57.0270
Var	12.092	3.943	280.3443

Statistics of 'data208.txt'

	Te	Ti	qi
Max	20.000	25.250	52.3840
Average	10.506	20.952	3.3961
Min	2.640	17.000	-57.1790
Var	12.033	3.856	280.1179

Statistics of 'data209.txt'

	Te	Ti	qi
Max	19.960	25.720	52.4230
Average	10.530	20.960	3.4070
Min	2.910	16.880	-57.1050
Var	12.248	3.942	280.2635

Statistics of 'data210.txt'

	Te	Ti	qi
Max	19.850	25.460	52.4790
Average	10.534	20.962	3.4067
Min	3.260	17.020	-57.1060
Var	12.095	3.899	280.4002

Statistics of 'data211.txt'

	Te	Ti	qi
Max	19.940	25.400	52.2470
Average	10.546	20.953	3.4129
Min	2.800	17.130	-57.1050
Var	12.176	3.905	280.3016

Statistics of 'data212.txt'

	Te	Ti	qi
Max	19.870	25.350	52.3910
Average	10.536	20.972	3.4099
Min	2.850	17.210	-57.1730
Var	12.054	3.898	280.3842

Statistics of 'data213.txt'

	Te	Ti	qi
Max	19.930	25.330	52.4330
Average	10.525	20.947	3.3972
Min	2.480	17.110	-57.1720
Var	12.009	3.855	280.2402

Statistics of 'data214.txt'

	Te	Ti	qi
Max	19.890	25.440	52.3670
Average	10.549	20.967	3.4104
Min	2.600	17.000	-57.1020
Var	12.179	3.904	280.5457

Statistics of 'data215.txt'

	Te	Ti	qi
Max	19.920	25.460	52.2770
Average	10.527	20.973	3.4092
Min	2.830	17.010	-57.1600
Var	12.274	3.892	280.4387

Statistics of 'data216.txt'

	Te	Ti	qi
Max	20.440	25.530	52.3720
Average	10.535	20.945	3.4063
Min	2.120	17.080	-57.2140
Var	12.081	3.870	280.4620

Statistics of 'data217.txt'

	Te	Ti	qi
Max	19.760	25.640	52.5400
Average	10.575	20.977	3.4119
Min	2.960	17.000	-57.0820
Var	12.180	3.883	280.2684

Statistics of 'data218.txt'

	Te	Ti	qi
Max	20.400	25.540	52.3090
Average	10.560	20.965	3.4139
Min	3.060	17.170	-56.9300
Var	12.236	3.925	280.3613

Statistics of 'data219.txt'

	Te	Ti	qi
Max	19.650	25.520	52.4250
Average	10.500	20.971	3.4048
Min	2.640	17.010	-56.8700
Var	12.266	3.914	280.3092

Statistics of 'data220.txt'

	Te	Ti	qi
Max	20.050	25.360	52.1470
Average	10.551	20.969	3.4031
Min	2.050	17.210	-57.0790
Var	12.107	3.890	280.2604

All data3xx files are of length 720

Statistics of 'data301.txt'

	Te	Ti	qi
Max	27.690	31.760	39.7790
Average	12.104	25.008	1.0739
Min	0.310	19.420	-36.3240
Var	18.457	6.350	318.1905

Statistics of 'data302.txt'

	Te	Ti	qi
Max	28.000	31.760	39.8010
Average	11.886	25.008	1.0742
Min	1.170	19.420	-36.3140
Var	19.010	6.350	318.1863

Statistics of 'data303.txt'

	Te	Ti	qi
Max	27.410	31.760	39.7860
Average	11.937	25.008	1.0736
Min	1.660	19.420	-36.3160
Var	18.728	6.350	318.1788

Statistics of 'data304.txt'

	Te	Ti	qi
Max	26.640	31.760	39.8040
Average	11.970	25.008	1.0740
Min	0.810	19.420	-36.2980
Var	19.135	6.350	318.2079

Statistics of 'data305.txt'

	Te	Ti	qi
Max	28.870	31.760	39.7760
Average	12.007	25.008	1.0743
Min	0.720	19.420	-36.3250
Var	19.157	6.350	318.1924

Statistics of 'data306.txt'

	Te	Ti	qi
Max	27.330	31.760	39.7790
Average	12.025	25.008	1.0739
Min	1.130	19.420	-36.3220
Var	18.007	6.350	318.1752

Statistics of 'data307.txt'

	Te	Ti	qi
Max	27.570	31.760	39.7850
Average	12.125	25.008	1.0733
Min	1.840	19.420	-36.3280
Var	17.979	6.350	318.1977

Statistics of 'data308.txt'

	Te	Ti	qi
Max	27.830	31.760	39.7920
Average	11.987	25.008	1.0743
Min	0.010	19.420	-36.3210
Var	18.538	6.350	318.2106

Statistics of 'data309.txt'

	Te	Ti	qi
Max	27.560	31.760	39.7970
Average	12.056	25.008	1.0742
Min	1.960	19.420	-36.3260
Var	18.234	6.350	318.1931

Statistics of 'data310.txt'

	Te	Ti	qi
Max	26.750	31.760	39.7950
Average	12.060	25.008	1.0737
Min	0.500	19.420	-36.3020
Var	19.262	6.350	318.1583

Statistics of 'data311.txt'

	Te	Ti	qi
Max	28.270	31.760	39.7910
Average	11.991	25.008	1.0742
Min	1.560	19.420	-36.3150
Var	17.491	6.350	318.2115

Statistics of 'data312.txt'

	Te	Ti	qi
Max	28.370	31.760	39.7830
Average	12.009	25.008	1.0736
Min	0.040	19.420	-36.3210
Var	18.436	6.350	318.2060

Statistics of 'data313.txt'

	Te	Ti	qi
Max	28.370	31.760	39.7830
Average	12.009	25.008	1.0736
Min	0.040	19.420	-36.3210
Var	18.436	6.350	318.2060

Statistics of 'data314.txt'

	Te	Ti	qi
Max	28.200	31.760	39.7870
Average	12.000	25.008	1.0735
Min	1.080	19.420	-36.3250
Var	18.480	6.350	318.1655

Statistics of 'data315.txt'

	Te	Ti	qi
Max	29.100	31.760	39.7900
Average	11.989	25.008	1.0740
Min	0.840	19.420	-36.3260
Var	18.003	6.350	318.2016

Statistics of 'data316.txt'

	Te	Ti	qi
Max	30.250	31.760	39.8090
Average	11.931	25.008	1.0741
Min	1.930	19.420	-36.3160
Var	19.981	6.350	318.1832

Statistics of 'data317.txt'

	Te	Ti	qi
Max	26.270	31.760	39.7820
Average	12.100	25.008	1.0737
Min	0.760	19.420	-36.3320
Var	18.562	6.350	318.1820

Statistics of 'data318.txt'

	Te	Ti	qi
Max	28.650	31.760	39.8180
Average	12.049	25.008	1.0738
Min	-0.720	19.420	-36.3260
Var	18.130	6.350	318.2013

Statistics of 'data319.txt'

	Te	Ti	qi
Max	29.890	31.760	39.7820
Average	11.961	25.008	1.0744
Min	1.140	19.420	-36.3080
Var	19.036	6.350	318.2041

Statistics of 'data320.txt'

	Te	Ti	qi
Max	27.020	31.760	39.8020
Average	12.002	25.008	1.0738
Min	0.700	19.420	-36.2980
Var	18.629	6.350	318.1946

Statistics of 'data41.txt'

	Te	Ti	qi
Max	28.560	27.600	4.3720
Average	18.095	21.333	1.0385
Min	9.400	17.000	-2.0880
Var	11.206	3.386	0.9486
Length	3360	3360	3360

Statistics of 'data42.txt'

	Te	Ti
Max	30.370	28.110
Average	19.536	22.914
Min	9.440	15.700
Var	12.955	2.654
Length	3360	3360

Statistics of 'data51.txt'

	Te	Ti	qi
Max	30.530	28.300	14.4400
Average	15.348	23.115	3.4631
Min	1.200	19.300	-5.5790
Var	35.211	4.218	20.3070
Length	1344	1344	1344

Statistics of 'data52.txt'

	Te	Ti
Max	29.220	26.210
Average	15.967	21.181
Min	7.180	16.540
Var	15.480	4.409
Length	1344	1344