Software Reliability Assessment for a Gearbox Controller by Analysis of Operating Experience

Sven Söhnlein[1], Francesca Saglietti[1], Franz Bitzer[2], Siegfried Baryschew

[1]*Chair of Software Engineering, Department of Computer Science, University Erlangen-Nuremberg, 91058 Erlangen, Germany {soehnlein, saglietti}@informatik.uni-erlangen.de*

[2]*LPE2-FB/Functions Basic Development, ZF Friedrichshafen AG, 88038 Friedrichshafen Germany, franz.bitzer@zf.com*

Abstract—This contribution summarizes the results of an ongoing feasibility study based on the evaluation of operational experience gained with a gearbox system for the purpose of estimating software reliability.

I. INTRODUCTION

The application of statistical sampling theory for the purpose of the quantitative assessment of software reliability usually requires a prohibitive effort, when applied during extensive testing phases [1, 3, 4]. The exploitation of past testing and operational activities actually helps to enhance its practical applicability [5, 6]. Tailored on its specific needs, a feasibility study on software reliability assessment is being conducted within an industrial research cooperation between academia and automotive industry. The practicality of the approach developed is demonstrated by its application to the control software of a gearbox system developed by the automotive supplier ZF Friedrichshafen AG. For reasons of confidentiality the data presented was previously rendered anonymous.

II. Software-controlled Gearbox System

The software controls twelve forward gears, two reverse gears and one neutral gear to be controlled manually by the driver or automatically by a driving assistant. In addition to the "current gear" CG and to the "desired gear" DG the functionality of the software controller also depends on further environmental parameters ρ_i, like the current speed, the accelerator pedal position, the brake pedal position and the retarder level.

A substantial amount of operational experience was collected during extensive road testing based on typical functional demands. The value of all relevant parameters was recorded at each point in time. Table 1 visualizes the data, where for reasons of confidentiality the individual gears are denoted by alphabetic symbols (a, b, c, …, m), while the environmental parameters ρ_i are provided on a percentage scale.

TABLE I. OPERATIONAL DATA RECORDED DURING ROAD TESTS

Time	DG
…	…
5.9	d
6.0	d
6.1	e
6.2	e
6.3	e
6.4	e
6.5	e
6.6	e
6.7	e
6.8	e
6.9	e
…	…

Time	CG
…	…
35.9	d
36.0	d
36.1	d
36.2	d
36.3	d
36.4	d
36.5	d
36.6	d
36.7	d
36.8	e
36.9	e
…	…

Time	ρ_1
…	…
25.9	10.60
26.0	11.29
26.1	11.70
26.2	11.90
26.3	12.01
26.4	12.01
26.5	11.80
26.6	12.90
26.7	12.51
26.8	12.60
26.9	12.80
…	…

…

1. Identification of functionality to be assessed: The scope of the assessment was focused on the software component implementing the gearbox control functions.

2. Operational independence of runs: The operational data collection was preceded by an initialisation phase devoted to parameter calibration after which the switching of gears performs in a memoryless way, i.e. the functionality of switching from gear c to gear d does not depend on previous switching operations, for example.

3. Structure of operational runs: Operational runs depend on the current gear CG, on the desired gear DC, as well as on four further parameters ρ_1, ρ_2, ρ_3 and ρ_4. Whenever a switching command was arisen by a driver or by the driving assistant, relevant operational data was identified (Table 2, at time 926.8 a switching command was risen and successfully completed at time 927.5). The set of all such relevant operational cases was extracted (Table 3).

TABLE II. RELEVANT OPERATIONAL CASE AT TIME 926.8

Time	DG	CG	ρ_1	ρ_2	ρ_3	ρ_4
…	…	…	…	…	…	…
926.0	g	g	4.50	0.4	21.6	0
926.1	g	g	4.19	0.4	21.6	0
926.2	g	g	3.89	0.4	21.6	0
926.3	g	g	3.69	0.8	21.6	0
926.4	g	g	3.39	0.4	21.6	0
926.5	g	g	3.00	0.4	21.6	0
926.6	g	g	3.00	0.4	21.6	0
926.7	g	g	2.50	0.4	21.6	0
926.8	**f**	**g**	**2.39**	**0.4**	**21.6**	**0**
926.9	f	g	2.00	0.0	21.6	0
927.0	f	g	2.00	0.0	21.6	0
927.1	f	g	2.00	0.4	21.6	0
927.2	f	g	1.09	0.4	21.2	0
927.3	f	g	1.09	0.4	21.2	0
927.4	f	g	1.09	0.4	21.2	0
927.5	f	f	1.09	0.0	21.2	0
927.6	f	f	1.00	0.0	21.2	0
…	…	…	…	…	…	…

TABLE III. OPERATIONAL CASES EXTRACTED

Time	CG	DG	ρ_1	ρ_2	ρ_3	ρ_4
…	…	…	…	…	…	…
5940,6	k	l	64,35	88,8	0,0	0
6012,3	l	j	57,55	0,4	0,0	0
6016,2	j	h	42,23	0,4	16,0	0
…	…	…	…	…	…	…

4. Determination of the operational profile: The frequencies of switching commands (i.e. of combinations (CG, DG)) were first determined on the basis of the operational data (Table 4).

TABLE IV. FREQUENCIES OF SWITCHING COMMANDS

	d	e	f	g	h	i	…
…	…	…	…	…	…	…	…
d	--	6.06	16.13	0.00	1.35	0.00	…
e	…	--	16.13	13.33	0.00	0.00	…
f	…	6.06	--	18.33	17.57	1.10	…
g	…	63.64	19.35	--	25.68	15.38	…
h	…	0.00	45.16	33.33	--	25.27	…
i	…	0.00	0.00	33.33	43.24	--	…
j	…	0.00	0.00	0.00	8.11	52.75	…
…	…	…	…	…	…	…	…

Successively, for each switching command (CG,DG) the profile of each parameter ρ_i, $i \in \{1…4\}$ was estimated by distribution fitting techniques [2]. A tool automatically supported the identification of the most suitable distribution classes as well as their parameters. The fit of each distribution was successively assessed by classical goodness-of-fit tests including the Kolmogorow-Smirnow, the Anderson-Darling and the χ^2 test [2]. Where fitting to generic distributions was not possible, empirical distributions were determined by linear interpolation of the samples collected.

5. Filtering of the operational data: In order to extract an independent subset of the recorded data, an approach was developed, which allows for the minimization of existing correlations among different operational demands by the application of evolutionary algorithms.

On the basis of the extracted data, reliability assessment will be carried out by applying statistical sampling theory [3, 4, 5, 6]. Moreover, component-specific reliability estimates can be combined by previously developed techniques [6, 7].

III. Conclusion

In this paper, a guideline for the estimation of software reliability by assessing operational experience was presented. The approach was illustrated by its practical application to a software-controlled gearbox system in the scope of an ongoing industrial feasibility study.

REFERENCES

[1] Butler, R., Finelli, G.: The Infeasibility of Quantifying the Reliability of Life-critical Real-time Software, Software Engineering, 19(1), 1993.

[2] Law, A. M., Kelton, W. D.: Simulation, Modeling and Analysis, McGraw-Hill, 2000.

[3] Littlewood, B., Wright, D.: Stopping Rules for Operational Testing of Safety Critical Software, Proc. 25th International Symposium Fault Tolerant Computing (FTCS 25), Pasadena, CA 1995.

[4] Miller, K. W., Morell, L. J., Noonan, R. E., Park, S. K., Nicol, D. M., Murrill, B. W., Voas, J. F.: Estimating the Probability of Failure When Testing Reveals No Failures, IEEE Transactions on Software Engineering, V. 18, No. 1, January 1992.

[5] Saglietti, F., Pinte, F., Söhnlein, S.: Integration and Reliability Testing for Component-based Software Systems, to be published in Proc. 35th EUROMICRO SEAA 2009 IEEE Computer Society Press, 2009.

[6] Söhnlein, S., Saglietti, F.: Software Reliability Estimation for Component-based Systems by Evaluation of Operational Experience gained with Components, 34th Euromicro Conference on Software Engineering and Advanced Applications, 2008.

[7] Söhnlein, S., Saglietti, F.: Software Reliability Assessment by Statistical Analysis of Operational Experience, ERCIM News no. 75, European Research Consortium for Informatics and Mathematics (ERCIM), 2008