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Technological Upgrade of Sisvar: 64-bit migration and Waller-Duncan multiple comparison test implementation.

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Abstract

In 2026, Sisvar completed thirty years of existence, with its first official release being implemented in Turbo Pascal in 1996. Since then, Sisvar has evolved from DOS to Windows, being subsequently developed in Delphi, and throughout this trajectory it has gained an increasing number of users. This success has been largely attributable to the high reliability and accuracy of its analytical results. Although it presented several limitations, such as the requirement for balanced designs in experimental data analyses, it also offered numerous competitive advantages over existing statistical software, particularly regarding the decomposition of crossed and nested factors in linear models, enabling mean tests and adjustments of linear regression models. The aforementioned advantages and disadvantages persist to the present day, although the negative aspects have been progressively mitigated at each stage of its development. Thus, in the commemorative year of its thirtieth anniversary, a major update was carried out. Among the implemented updates, we highlight the 64-bit migration to comply with modern operating systems and computers, and the removal of the outdated Paradox and Dbase databases (BDE and DBExpress), which were replaced by the FireDAC database. FireDAC is a high-performance component library for universal data access, developed by Embarcadero for Delphi and C++Builder. It enables fast and native connectivity of applications to several relational databases, such as Firebird, MySQL, SQL Server, Oracle, and SQLite. Furthermore, several minor bug fixes were performed, and one of the most noteworthy incorporations of new methods is the implementation of the Waller-Duncan multiple comparisons test. After 30 years of existence, Sisvar remains free of charge and is made available on my personal page at the following addresses: Personal Home Page and Download Sisvar.

Keywords: Waller-Duncan test, multiple comparisons, FireDAC, BDE, agricultural statistics.

1. Introduction

Sisvar is a statistical analysis and experimental design software well-established in the Portuguese-speaking national and international scientific community. Since its creation, Sisvar has encompassed methods for analysis of variance (ANOVA) for various designs (any model can be analyzed). The models are limited to a maximum of 100 sources of variation plus 50 sources of variation for error terms, as in split-plot, split-block, and other designs. Moreover, for each source of variation, it is possible to apply mean comparison tests such as Tukey, Scott-Knott, Duncan, SNK, among others. Additionally, applications of orthogonal or non-orthogonal contrasts and regression are allowed when the levels of the factor under analysis are quantitative. Linear regression models, including polynomial regressions, are permitted. If the sources of variation are crossed or nested effects, multiple comparison tests, contrasts, or regression are allowed in the breakdowns of one of the factors composing that source of variation in relation to the others. Sisvar allows multiple linear regression adjustments with or without the application of additional model selection methods, such as backward, forward, and stepwise. Several elementary statistical methods are also available, including tests and interval estimation for binomial proportions, tests and estimation of a population mean, tests and estimation of the difference between two population means, random generation of experimental designs, and the Shapiro-Wilk normality test (Ferreira, 2019; Ferreira, 2011; Ferreira, 2014).

Furthermore, Sisvar features an analysis module for performing multiple comparison procedures via bootstrap (Ferreira, 2014). In this module, comparisons of treatments against a control or check treatment are possible. This test is analogous to Dunnett's test, but since it is performed via bootstrap, it does not require error normality. Moreover, bootstrap comparisons are available for treatment means taken two by two. The available options are tests analogous to Tukey, SNK, and Scott-Knott (SK). The user may choose the number of bootstrap resamples to be performed. The program returns the requested multiple comparison tests and the ANOVA via bootstrap. The modernized Sisvar remains free and open-source software, available at the following address: Download Sisvar. The old version is still maintained at: Personal Home Page.

In the following, we present the evolution of the new Sisvar, namely Sisvar 6.6 64-bit. We will show the changes implemented and the technical benefits provided, and then we will present the newly implemented multiple comparison method. With the implemented changes, the possibility arises for improvements in the implementation of new univariate and multivariate analysis methods, as well as the possibility of making its source code available to the scientific community in the near future.

2. Sisvar 6.6 - 64-bits

Although a 32-bit version was also generated for potential compatibility with older 32-bit computers of some users, the focus remained on the 64-bit version. The free version of Embarcadero Delphi 12 was used to build the Sisvar 6.6 64-bit version. A 64-bit version Linux was also generated using Lazarus, which is a professional open-source and cross-platform IDE based on Free Pascal, but it is not a stable version yet. The migration of Sisvar to Delphi 12 with 64-bit architecture and the FireDAC database engine represents a massive technological leap. The system has abandoned obsolete technologies from the 1990s (BDE and 32-bit) and adopted the modern software industry standard.

By compiling Sisvar in 64-bit, the main advantages are related to infrastructure, hardware capacity, and system longevity: breaking the memory barrier, since 32-bit applications can manage at most 2 GB to 4 GB of RAM. In 64-bit, Sisvar gains practical access to terabytes of RAM, completely eliminating Out of Memory errors when processing large volumes of statistical data. Performance in mathematical computations: modern processors work natively in 64-bit. Win64 compilation

takes advantage of wider registers (such as SSE/AVX instructions), allowing Sisvar to perform variance calculations, regressions, and complex mathematical analyses much faster. Compatibility and future support: modern operating systems (such as Windows 11 and modern Windows Server) prioritize or require 64-bit architectures. This ensures that Sisvar will continue to run perfectly in the coming decades without relying on emulation layers (WoW64). Integration with modern DLLs: Sisvar can now interact natively with other modern 64-bit libraries, drivers, and plugins (such as report generators and spreadsheet exporters).

The Borland Database Engine (BDE) was discontinued over twenty years ago and was the biggest bottleneck in Sisvar. With FireDAC, the system gained: extreme data access speed: FireDAC is one of the fastest data engines in the world market. It utilizes native features of each database (such as parameter arrays and asynchronous fetching), which drastically accelerates reading and writing of dense tables. Support for modern databases. BDE was limited to outdated technologies such as Paradox and dBase, or unstable connections via ODBC. FireDAC connects natively and with full security to current DBMSs such as PostgreSQL, MySQL, SQL Server, Oracle, and SQLite. Intelligent memory management. End of chronic configuration errors: BDE required manual installation and configuration of the "BDE Administrator" on the client machine, generating frequent Network Initialization Error or file limit errors (MaxFileHandles). FireDAC is Zero-Configuration: simply install Sisvar, and the database DLLs come bundled with the executable.

By combining Delphi 12 (64-bit) with FireDAC, Sisvar has become truly efficient and resilient software for the current technological landscape. The combination of the mathematical and memory capability of 64-bit with the robustness and speed of FireDAC means that Sisvar can now handle massive scientific datasets. In doing so, improvements in file import were carried out, and this represented a major leap in the ease with which users will find to perform their analyses. The new Sisvar now allows direct import of Excel, CSV, and LibreOffice files into FireDAC database tables without the user needing to know anything about databases. This is one of the great differentiators that the new interface and implementation have brought to Sisvar's loyal users. The other novelty concerns the Waller-Duncan multiple comparison method, which is discussed in the next section.

3. Waller-Duncan Multiple Comparison Procedure

Multiple comparison procedures (MCPs) are essential for post-hoc mean comparisons in designed experiments, especially within agricultural and biological research, where numerous treatment means are typically contrasted subsequent to a significant ANOVA F-test. Among the various MCPs available in the statistical literature, the Waller-Duncan test (Waller & Duncan, 1969; Waller & Duncan, 1972; Waller & Kemp, 1975b; Waller & Kemp, 1975a) stands out due to its foundation on Bayesian decision theory, which departs from the conventional frequentist paradigm of controlling family-wise Type I error rates.

In contrast to classical methods such as Tukey's HSD or Duncan's Multiple Range Test, the Waller-Duncan procedure explicitly accounts for the relative costs associated with Type I and Type II errors through the specification of a *k-ratio* (Waller & Duncan, 1969). This ratio, commonly set to $k = 100$ in typical agricultural applications, quantifies the researcher's assessment that erroneously identifying two treatment means as different (Type I error) is approximately 100 times more detrimental than overlooking an actual difference (Type II error). The critical threshold for declaring significance is determined by minimizing the Bayes risk under an additive loss structure, yielding the following implicit condition:

$$t_{\text{crit}} = \inf \left\{ t : k \leq \frac{\int_1^\infty n_0(x, t) dx}{\int_1^\infty d_0(x, t) dx} \right\} \quad (1)$$

where $n_0(x, t)$ and $d_0(x, t)$ denote functions that incorporate the non-central t-distribution, the ANOVA F-statistic, the number of treatments q , and the error degrees of freedom f (Waller &

Kemp, 1975b). As Equation 1 lacks an analytical closed-form solution, numerical integration techniques are required for its evaluation.

The updated version of Sisvar incorporates a numerically stable algorithm for determining Waller-Duncan critical values, which overcomes two major challenges found in existing software implementations. First, current implementations available in the R package *agricolae* (Mendiburu, 2023) and the Python package *scikit-posthocs* (Terpilowski, 2019) rely on adaptive Gaussian quadrature but become unstable or fail entirely when the number of treatments q or the error degrees of freedom f exceed 100. Second, although the SAS PROC GLM procedure with the WALLER option (SAS Institute Inc., 2023) provides reliable solutions for large-scale problems, its proprietary nature restricts accessibility for many academic and non-commercial users.

The Waller-Duncan procedure proves particularly advantageous in several research scenarios, including: field and greenhouse experiments in agriculture (Petersen, 1994; Steel *et al.*, 1997; Carmer, 1976); quality assurance and industrial process monitoring (Montgomery, 2022); and genomic applications along with other high-dimensional data analyses (Efron, 2010). Its flexibility in accommodating different k-ratio values makes it a versatile tool for researchers who wish to calibrate the trade-off between false discoveries and missed detections according to the specific costs inherent to their experimental contexts.

4. Conclusion

The thirtieth anniversary of Sisvar marks not only a chronological milestone but also a significant technological turning point for the software. The migration from a 32-bit architecture based on obsolete Borland Database Engine (BDE) technologies to a modern 64-bit platform integrated with the FireDAC database framework has substantially enhanced the software's performance, scalability, and user experience. The new architecture effectively removes memory constraints that previously limited the analysis of large datasets, while the native connectivity to contemporary relational databases ensures seamless data import and export capabilities.

Among the several improvements introduced in Sisvar 6.6, the implementation of the Waller-Duncan multiple comparison test stands out as a noteworthy methodological advancement. The numerically stable algorithm developed for computing critical values addresses key limitations found in existing open-source implementations, particularly regarding convergence and stability when dealing with large numbers of treatments or error degrees of freedom. This enhancement broadens the applicability of Sisvar to high-dimensional experimental contexts, including genomic studies and complex agricultural trials.

Furthermore, the adoption of a zero-configuration database engine, combined with direct support for widely used file formats such as Excel, CSV, and LibreOffice, considerably lowers the technical barrier for end-users, allowing researchers to focus on statistical interpretation rather than data management intricacies. The decision to maintain both 32-bit and 64-bit versions, while prioritizing the latter, reflects a balanced commitment to legacy user support and future-oriented development.

Looking ahead, the technological foundation established by the 64-bit migration and FireDAC integration opens promising avenues for further methodological enhancements. Planned developments include the implementation of additional univariate and multivariate analysis techniques, as well as the potential release of the source code to the scientific community, which would foster collaborative contributions and transparency. As Sisvar enters its fourth decade, it remains a free, reliable, and increasingly powerful tool for the statistical analysis of designed experiments, reaffirming its commitment to supporting agricultural and biological research in Portuguese-speaking countries and beyond.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Ferreira, D.F. **Formal analysis:** Ferreira, D.F. **Funding acquisition:** Ferreira, D.F. **Investigation:** Ferreira, D.F. **Methodology:** Ferreira, D.F. **Project administration:** Ferreira, D.F. **Software:** Ferreira, D.F. **Resources:** Ferreira, D.F. **Supervision:** Ferreira, D.F. **Validation:** Ferreira, D.F. **Visualization:** Ferreira, D.F. **Writing – original draft:** Ferreira, D.F. **Writing – review and editing:** Ferreira, D.F.

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