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# Nonparametric testing for time series: a bibliography

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**Key words and phrases:** Permutation tests, sign tests, rank tests, tests against ordered alternatives, binary and multiple runs, quotas, records, Markov chain models.

**AMS 1980 subject classifications:** Primary 62G10; secondary 62M10, 00A15.

## ABSTRACT

This bibliography brings together and classifies a wide variety of nonparametric methods which are potentially useful for the analysis of time series data, in particular for testing randomness. Inference on Markov chain models is also extensively surveyed.

## 1. INTRODUCTION

The purpose of this bibliography is to bring together a number of results which are potentially useful for analyzing time series in a nonparametric way (without the normality or a similarly specific assumption) and for dealing with categorical time series. The unifying characteristic of the methods assembled here is that they are based on instruments such as: runs, signs, ranks, permutations, frequency counts, records, quotas. They are mainly tests of the null hypothesis of independence (or randomness) of random variables in a discrete time series and of randomness of occurrences of certain events in continuous time. The main alternatives considered are: monotonic or cyclic trends, serial dependence (or correlation), clustering of events in time (or, more generally, along a line), Markov chain models, and dependence between time series. For the case of Markov chain models, both estimation and testing are considered; although this topic is somewhat less "nonparametric" than the others, it is included because it is closely related to the analysis of runs and represents one of the simplest ways of analyzing categorical time series.

To be more specific, topics covered fairly extensively include:

- (a) permutation, sign and rank tests against trend in location (monotonic, cyclic, etc.) or serial dependence;
- (b) tests against ordered alternatives (a form of trend monotonic in location);
- (c) tests based on records;
- (d) the literature on binary and multiple runs (distribution theory and inference based on runs); some references to quotas;
- (e) inference on Markov chain models (estimation and testing);
- (f) nonparametric tests of independence between two (or several) time series;
- (g) tests for clustering of events in time (discrete or continuous) or, more generally, for clustering of points along a line; this includes also tests against clustering in free recall (in psychology, the occurrence of sequences of related items in the free recall of a randomly ordered stimulus list);
- (h) various tests of randomness of points along a line;

- (i) tests for birth order effect (in genetics, whether birth-rank has an effect on a given defect or character);
- (j) nonparametric tests against trend in dispersion.

The bibliography contains 606 references and covers the period 1926–1979, although the post-1940 period was more extensively surveyed. On the problem of testing randomness (against trend or serial dependence), it updates the bibliographies of Savage (1953p, 1962p) and is much more complete than those of Naus (1979n) and Singer (1979s). There is very limited overlap between our bibliography and the latter two, which did not stress time series applications. For a more extensive bibliography of the literature on clusters, clumps and coincidences, the reader is referred to Naus (1979n). On statistical inference concerning Markov chain models, we update the survey of Billingsley (1961d).

Of course, in order to avoid making the bibliography too extensive, several related topics had to be excluded. For example, we did not cover the vast literature on standard serial correlation methods as well as spectral analysis (for the analysis of cyclic trends); though the distributions of the statistics involved by these methods generally depend in finite samples on the normality assumption, these may be relatively robust in large samples (at least with respect to certain classes of distributions); for extensive references on these topics, the reader is referred to Wold (1965p), Hannan (1970), Anderson (1971) and Brillinger (1975, 1980). In particular, on ways of robustifying spectral analysis, see Kleiner, Martin and Thompson (1979). Similarly, another related topic not covered by our bibliography is the robustness of nonparametric estimators for dependent data, as studied, for example, by Gastwirth and Rubin (1975). [The references to all authors cited in this paragraph, except Wold, are given on page 38.]

The references are presented in chronological order, which should help one to understand the historical development of the topics involved. A classification by topics, particularly by types of alternatives considered and by types of instruments used (signs, ranks, permutations, etc.) is also provided. To keep the bibliography to a manageable size, it was limited mainly to work published in periodicals and collections (proceedings, etc.); a number of Ph.D. dissertations and specialized monographs were also included; textbooks, technical reports and abstracts were in general excluded.

Our hope is that the bringing together of this widely scattered material from several streams of research will facilitate the use of nonparametric methods in the analysis of time series and encourage research on such methods.

The subject codes and index are given in Section 2, the bibliography in chronological order is in Section 3, while an alphabetical listing of the authors appears in Section 4.

## 2. SUBJECT CODES AND INDEX

The references are to the last two numbers of the year of publication.

- A: General [41a, b], [44b], [57l], [60a], [69b], [70a], [74a].
- AX: Auxiliary mathematical or statistical results [36b], [39a], [40d], [42f], [43i], [45h], [47d, f, h], [49b, c], [50g, i], [51d, g, o], [52c], [53h], [55g, l], [56d], [57b], [59i].
- B: Bibliographies, surveys [43a], [46e], [50h], [53p], [55d], [62e, p], [65a, e, l, p], [69d], [72b], [76h], [77n], [78g, m], [79n, s].

- BO: Tests against birth order effect (genetics) [48c], [52g], [58c, e], [59b], [64a], [68d].
- CL: Tests against clustering (see also BO, CLFR, RO) [63o], [64e, g, h], [65b, c, g], [66e, g, h], [67f], [68g, p, q], [70m, n], [71g, m], [72m], [73a, l, z, aa], [74g, m, p], [75f, k, u], [76p, q], [77f, u], [79n, t].
- CLFR: Tests against clustering in free recall (psychology) [53b], [56j], [62q], [64c], [66b], [68b], [69c, m], [70c], [71e, l], [73k], [74e], [75a, q], [76k].
- CP: Computer programs [70e], [71h, k], [73bb], [72l], [74m], [76f], [77o].
- M: Miscellaneous tests of randomness and applications [29a], [34a], [38a, b, c, f], [39b, c], [46b], [47b, e], [48b], [49f], [50d], [51c, e], [52d].
- MC: Inference on Markov chains [47a], [48a], [49d], [50c], [51a, b, g], [52a, f, i, l, m], [53d, e, f, g, i, n], [54b, g, m, n, o], [55b, i, j, m, n, o, r], [56h, i, l], [57a, d, e, f, g, h, k, o, q], [58d, e, f, g, h, i, j, k, l, m], [59c, d, f, g, h, j, k, l, m, o], [60b, c, e, f, g], [61b, c, d, j, l], [62a, g, i, j], [63d, e, n, p], [64f], [65h, m, n], [66a, c, f], [67c], [68e, i, j, l, o], [69e, h, j, k, l], [70b, d, f, h, i, j, k], [71a, b, c, h, j], [72a, c, e, f, g, j, k, m, n, q, t], [73b, c, e, f, g, h, j, n, t, bb], [74c, d, g, i, n, q], [75b, c, m, o, w, z, aa], [76c, d, m, s, t, w, x], [77d, h, l, m, q, r, v], [78a, b, c, d, f, g, h, i, j, k, l, p, r, s, w, x], [79b, c, d, e, f, g, h, l, m, p, r, u].
- MRU: Multiple runs (see also MC) [45d], [54f], [57c, h], [59a], [69f], [71d], [76u], [77b].
- MS: Multiple series (mainly tests of independence between time series) [41e], [42b, d], [43d], [52o], [61k], [63f], [65o], [68a], [76i, w].
- OA: Tests against ordered alternatives (trend in location) [47f], [51o], [53q], [54i, j], [55a], [59e, p], [60d], [61a], [62d], [63a, c, j], [64b], [65k], [66d], [67b, d, e, i], [68c, m, n], [70p], [71i], [72b, o, p], [73d, x], [74l], [75h, n, r, y], [76a, b, j, n, o], [77c, j, k, s, t], [78q, u, y, z, bb, cc], [79j, k, q].
- P: Permutation tests [39a], [41d, f], [42a, e], [43f, g, h, i], [45a, b], [50k], [51k], [53h], [54e, q], [67f], [70m, n], [72l], [73m], [75g, p], [76f].
- PW: Power comparisons included [36b], [47a], [48a], [49d], [50k], [52j, o, p], [54q], [55f, h], [56k, o], [57p], [59b], [62k], [64b], [66h, i], [68h], [69i], [70o, q], [72i, n, o], [75d], [76j, r], [77g, p], [78e], [79a].
- Q: Quotas [59n], [62h, l], [65d], [66c], [68f], [70g], [72u], [73s], [74k], [75i], [76l].
- RA: Tests of randomness based on ranks (see also BO, OA) [36b], [38d], [39a], [42a], [43h], [45g], [47f, h], [49a, e], [50a, b, h, i, j, m], [51f, o], [52p], [54q], [55e, f, g], [56d, g, k, o], [57l, m], [58a], [62k], [69a], [70l, o], [72d, i, v], [74b], [75d, e, j], [76j, r], [77a, e, g], [78e, aa], [79a, k].
- RE: Records [27a], [36c], [43c], [49b], [52b], [54d], [55f, h], [56k], [57b, p], [59q], [60h], [62e, n, o], [64d], [65a], [67g], [69g, n], [70r], [72r, s], [73h, i, o, p, q, r, u, y], [74d, o], [75t, x], [76e, g, v], [78m, v].
- RO: Tests of the randomness of points along a line (see also CL) [33a], [38e], [39d], [45h], [46e], [47d, g], [48d], [49c], [50e, f, l], [51h, i, j, n], [52h, k], [53a, c, m, o], [54c], [55c, d], [56a, b, c, e, f], [57n], [61g], [62b, f], [63h, i, k], [65l], [68q], [70q], [73z], [75i], [77i, p], [78t].
- RU: Runs (see also CL, CLFR, MRU, MC, Q) [26a, b], [29b], [36a], [37a, b, c, d, e], [38b], [39e, f], [40a, b, c, d], [41c, e], [42b, c, d, f], [43b, d, j], [44a, c, d], [45c, e, f], [46a, c, d, f], [47a, c], [48a, d], [49d], [50f, g, h, n], [51l, m, n], [52e, h, j, m, n], [53j, k, r], [54k, l, p, q, s], [55k, l, p, q], [56m, o], [57b, h, i, j], [58a, b, m, n, o, p], [59a, h, i, n], [60h], [61e, f, h, i, m], [62c, e, h, l, m], [63b, g, l, m], [65a, f, i, j], [66f], [67a, h], [68k], [69d, i, l], [70e], [71f], [72h], [73g, v, w], [74f, h, j, n, r], [75l, s, v], [77f, n, o, u], [78h, n, o], [79i, o].
- S: Tests of randomness based on signs (see also RU) [27b], [29b], [41e], [42b, d], [43d, e], [45e, f], [50n], [51d, e], [52h, o], [53l], [54h, q, r], [55d, e, l], [56n], [61h, k], [63g], [66i], [68h], [69d].
- SD: Tests against serial dependence (or serial correlation) [36b], [41f], [43h], [50k], [51e], [53f], [54a, e], [63g], [69a], [70l], [72d, l], [73m], [75p], [77g].

- TB: Table provided [34a], [39c], [43e], [47c, h], [51l], [54f], [55p], [59h], [61h], [68n], [71i], [76p], [78z].
- TR: Tests against trend in location (see also OA, SD) [26a], [27b], [29b], [36a], [41e], [42b, d, f], [43d], [45f, g], [47f], [50a, b, h, j, k], [51d, f, o], [52o, p], [54d, h, r], [55d, e, f, h], [56a, n, o], [57m, p], [62k], [65e], [68a], [69a, d, i], [70o], [71k], [72h, i, l, w], [74b], [75d, e, g, j], [76f, r], [77a, e], [78e, aa, dd], [79a, k].
- TRD: Tests against trend in dispersion [55e], [66i], [68h], [79j].

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## APPENDIX

### JOURNAL ABBREVIATIONS USED

- Acad. Roy. Belg. Bull. Cl. Sci. Ser. 5:* Académie Royale de Belgique, Bulletin de la Classe des Sciences, 5e Série.  
*Adv. in Appl. Probab.:* Advances in Applied Probability.  
*Akad. Nauk Uzbek. SSR Trudy Inst. Mat. Meh.:* Akademija Nauk Uzbekskoi SSR. Trudy Instituta Matematiki i Mehaniki imeni V.I. Romanovskogo.

- Amer. J. Epidem.*: American Journal of Epidemiology.
- Amer. J. Sociol.*: American Journal of Sociology.
- Amer. Math. Monthly*: American Mathematical Monthly.
- Amer. Statist.*: The American Statistician.
- An. Univ. C.I. Parhon Bucureşti Ser. řti. Natur.*: Analele Universităii "C.I. Parhon" Bucureşti. Seria řtiinþelor Naturii.
- Ann. Eugenics*: Annals of Eugenics.
- Ann. Fac. Sci. Univ. Clermont*: Annales de la Faculté des Sciences de l'Université de Clermont.
- Ann. Human Genet.*: Annals of Human Genetics.
- Ann. Inst. Statist. Math.*: Annals of the Institute of Statistical Mathematics (Tokyo).
- Ann. Math. Statist.*: The Annals of Mathematical Statistics.
- Ann. of Math.*: Annals of Mathematics.
- Ann. Polon. Math.*: Annales de la Société Polonaise de Mathématiques.
- Ann. Probab.*: Annals of Probability.
- Ann. Sci. Math. Québec*: Annales des Sciences Mathématiques du Québec.
- Ann. Statist.*: The Annals of Statistics.
- Ann. Univ. Mariae Curie-Skłodowska Sect. A*: Annales Universitatis Mariae Curie-Skłodowska Section A.
- Apl. Mat.*: Československá Akademie Věd. Aplikace Matematiky (Prague).
- Appl. Statist.*: Applied Statistics.
- Ark. Mat.*: Arkiv för Matematik.
- Astronom. Nachr.*: Astronomische Nachrichten.
- Austral. J. Statist.*: The Australian Journal of Statistics.
- Bacteriol. Rev.*: Bacteriological Review.
- Behav. Res. Methods Instrumentation*: Behavior Research Methods and Instrumentation.
- Bell System Tech. J.*: Bell System Technical Journal.
- Biom. Z.*: Biometrische Zeitschrift.
- Biometrical J.*: Biometrical Journal.
- Biometrics*: Biometrics.
- Biometrika*: Biometrika.
- British J. Math. Statist. Psychol.*: The British Journal of Mathematical and Statistical Psychology.
- British J. Prevent. Soc. Med.*: British Journal of Preventive and Social Medicine.
- British J. Statist. Psychol.*: British Journal of Statistical Psychology.
- Bull. Acad. Polon. Sci. Sér. Sci. Math. Astronom. Phys.*: Bulletin de l'Académie Polonaise des Sciences, Série des Sciences Mathématiques, Astronomiques et Physiques.
- Bull. Inst. Internat. Statist.*: Bulletin de l'Institut International de Statistique.
- Bull. Math. Soc. Sci. Math. Phys. R.P. Roumaine*: Bulletin Mathématique de la Société des Sciences Mathématiques et Physiques de la République Populaire Roumaine.
- Bull. Math. Statist.*: Bulletin of Mathematical Statistics.
- Canad. Psychol. Rev.*: Canadian Psychological Review.
- Cancer*: Cancer.
- Cancer Res.*: Cancer Research.
- Colloq. Anal. Statist. Bruxelles*: Colloque sur l'Analyse Statistique, Bruxelles.
- Colloq. Math.*: Colloquium Mathematicum.
- Comm. Pure Appl. Math.*: Communications on Pure and Applied Mathematics.
- Comm. Statist.*: Communications in Statistics.
- Comm. Statist. A—Theory Methods*: Communications in Statistics, Part A—Theory and Methods.
- Comm. Statist. B—Simulation Comput.*: Communications in Statistics, Part B—Simulation and Computation.
- C.R. Acad. Sci. Paris*: Comptes Rendus Hebdomadaires de l'Académie des Sciences de Paris.
- Dissertationes Math.*: Dissertationes Mathematicae (Warsaw).

- Dokl. Akad. Nauk SSSR.*: Doklady Akademija Nauk SSSR.
- Duke Math. J.*: Duke Mathematical Journal.
- Econometrica*: Econometrica.
- Educ. Psychol. Meas.*: Educational and Psychological Measurement.
- Experientia*: Experientia.
- Indust. Engrg. Chem.*: Industrial and Engineering Chemistry.
- Inform. and Control*: Information and Control.
- Internat. J. Systems Sci.*: International Journal of Systems Science.
- Internat. Statist. Rev.*: International Statistical Review.
- IRE Trans. Information Theory*: IRE Transactions on Information Theory.
- İstanbul Univ. Fen Fak. Mecm. Ser. A.*: Revue de la Faculté des Sciences de l'Université d'Istanbul, Série A. Mathématiques Pures et Appliquées.
- Izv. Akad. Nauk UzSSR. Ser. Fiz. Mat. Nauk*: Izvestija Akademii Nauk UzSSR. Serija Fiziko-Matematičeskikh Nauk.
- J. Amer. Statist. Assoc.*: Journal of the American Statistical Association.
- J. Appl. Probab.*: Journal of Applied Probability.
- J. General Psychol.*: Journal of General Psychology.
- J. Indian Soc. Agric. Statist.*: Journal of the Indian Society of Agricultural Statistics.
- J. Madras Univ. Sect. B*: Journal of Madras University B. Contributions in Mathematics, Physical and Biological Sciences.
- J. Math. Psychol.*: Journal of Mathematical Psychology.
- J. Meteorol. Geogr.*: Journal of Meteorologic Geography.
- J. Multivariate Anal.*: Journal of Multivariate Analysis.
- J. Qual. Technol.*: Journal of Quality Technology.
- J. Res. Nat. Bur. Standards Sect. B*: Journal of Research of the National Bureau of Standards, Section B.
- J. Roy. Statist. Soc. Ser. A (Ser. B)*: Journal of the Royal Statistical Society Series A (Series B).
- J. Sci. Météorol.*: Journal Scientifique de la Météorologie.
- J. Statist. Comput. Simulation*: Journal of Statistical Computation and Simulation.
- J. Verbal Learn. Verbal Behav.*: Journal of Verbal Learning and Verbal Behavior.
- Magyar Tud. Akad. Mat. Fiz. Oszt. Közl.*: A Magyar Tudományos Akadémia Matematikai és Fizikai Tudományok Osztályának Közleményei.
- Mat. Fiz. Lapok*: Matematikai és Fizikai Lapok.
- Math. Ann.*: Mathematische Annalen.
- Math. Mag.*: Mathematics Magazine.
- Math. Operationsforsch. Statist. Ser. Statist.*: Mathematische Operationsforschung und Statistik, Series Statistics.
- Math. Student*: Mathematics Student.
- Math. Tables Aids Comput.*: Mathematical Tables and Other Aids to Computation.
- Mathematika*: Mathematika.
- Metrika*: Metrika.
- Metron*: Metron.
- Nature*: Nature.
- Nederl. Akad. Wetensch. Proc. Ser. A*: Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series A.
- Operations Res.*: Operations Research.
- Philos. Bull.*: Philosophical Bulletin.
- Philos. Mag.*: Philosophical Magazine.
- Philos. Trans. Roy. Soc. London Ser. B*: Philosophical Transactions of the Royal Society of London, Series B.
- Problems Control Inform. Theory*: Problems of Control and Information Theory.
- Proc. Cambridge Philos. Soc.*: Proceedings of the Cambridge Philosophical Society.

- Proc. Fifth Berkeley Symp. Math. Statist. Probab.*: Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability.
- Proc. Roy. Soc. Edinburgh*: Proceedings of the Royal Society of Edinburgh.
- Proc. Second Berkeley Symp. Math. Statist. Probab.*: Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability.
- Proc. Second Symp. Comput. Statist. (Berlin West)*: Proceedings in Computational Statistics, Second Symposium held in Berlin (West).
- Proc. Sixth Berkeley Symp. Math. Statist. Probab.*: Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability.
- Proc. Symp. to Honor Jerzy Neyman*: Proceedings of the Symposium to Honor Jerzy Neyman.
- Przegląd Statyst.*: Przegląd Statystyczny.
- Psychol. Bull.*: Psychological Bulletin.
- Psychol. Rep.*: Psychological Report.
- Psychol. Rev.*: Psychological Review.
- Psychonomic Sci.*: Psychonomic Science.
- Psychometrika*: Psychometrika.
- Publ. Inst. Statist. Univ. Paris*: Publications de l'Institut de Statistique de l'Université de Paris.
- Publ. Sci. Tech. Minist. Air*: Publications Scientifiques et Techniques du Ministère de l'Air.
- Quart. J. Roy. Meteorol. Soc.*: Quarterly Journal of the Royal Meteorological Society.
- Rep. Third Annual Conf. Econ. Statist.*: Report of the Third Annual Research Conference on Economics and Statistics.
- Rev. Econom. Statist.*: Review of Economic Statistics.
- Rev. Math. Un. Interbalk.*: Revue Mathématique de l'Union Interbalkanique.
- Sankhyā*: *Sankhyā. The Indian Journal of Statistics*.
- Scand. Actuar. J.*: Scandinavian Actuarial Journal.
- Scand. J. Statist.*: Scandinavian Journal of Statistics.
- Sci. and Cult.*: Science and Culture.
- Serdica*: Serdica Bulgaricae Mathematicae Publications.
- SIAM Rev.*: SIAM Review.
- Skand. Aktuarietidskr.*: Skandinavisk Aktuarietidskrift.
- South African Statist. J.*: South African Statistical Journal.
- Statistica Neerlandica*: Statistica Neerlandica.
- Stochastic Process. Appl.*: Stochastic Processes and their Applications.
- Stochastics*: Stochastics.
- Studia Sci. Math. Hungar.*: Studia Scientiarum Mathematicarum Hungarica.
- Studii Cerc. Mat.*: Studii și Cercetăria Matematică.
- Technometrics*: Technometrics.
- Teor. Verojatnost. i Primenen.*: Teorija Verojatnosti i ee Primenenija.
- Theory Probab. Appl.*: Theory of Probability and its Applications.
- Vestnik Leningrad. Univ.*: Vestnik Leningradskogo Universiteta.
- Wiss. Z. Tech. Univ. Dresden*: Wissenschaftliche Zeitschrift der technischen Universität Dresden.
- Z. Wahrsch. Verw. Gebiete*: Zeitschrift für Wahrscheinlichkeitstheorie und verwandte Gebiete.
- Zastos. Mat.*: Zastosowania Matematyki. Polskiej Akademii Nauk Instytut Matematyczny.

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## RÉSUMÉ

Cette bibliographie réunit et classe un grand nombre de méthodes non paramétriques qui peuvent servir à analyser les séries chronologiques, et à en tester, entre autres, le caractère aléatoire. On fait également le bilan des travaux parus à ce jour concernant l'inférence sur les chaînes de Markov.

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