UNIVERSIDAD DE GRANADA

FACULTAD DE CIENCIAS

Propuesta TFG. Curso 2026/2027

GRADO: Grado en Matemáticas

CÓDIGO DEL TFG: 270-071-2026/2027

1. DATOS BÁSICOS DEL TFG:

Título: Modelos multi-estados en el campo de la Fiabilidad

Descripción general (resumen y metodología):

Hoy día es de especial interés, en el análisis de tiempos de vida, el estudio de la evolución y el análisis del comportamiento de sistemas (fiabilidad) que atraviesan distintos estados a lo largo del tiempo. Los modelos multi-estados son modelos que estudian el problema mencionado anteriormente.

El campo de aplicación de los modelos multi-estados es muy amplio resaltando el de la fiabilidad. Se han considerado modelos multi-estados (MSS) en la modelización de sistemas que atraviesan distintas etapas en su funcionamiento, como son sistemas unitarios, redundantes, con degradación, mantenimiento preventivo,...

Son diversas las técnicas utilizadas en la modelización de sistemas multi-estados. Los procesos de Markov permiten el estudio y modelización de sistemas multi-estados de una forma algorítmica, bien estructurada, obteniendo medidas de interés implementables computacionalmente. Específicamente es de al to interés la incorporación de la distribuciones tipo fase, así como de los procesos de llegadas markovianas y sus extensiones.

Se realizará una revisión bibliográfica actualizada y se aplicarán los resultados obtenidos en el campo de la fiabilidad o supervivencia con Matlab y R.

Tipología: Estudio de casos, teóricos o prácticos, relacionados con la temática del Grado.

Objetivos planteados:

- Conocer las medidas y los modelos clásicos en fiabilidad.
- Modelizar el comportamiento de un tiempo de vida mediante un modelo multi-estados
- Obtener medidas de interés desde un punto de vista teórico
- Estimar el modelo desde el conjunto de datos o realizar simulaciones
- Validar e interpretar los resultados
- Empleo y estudio del correspondiente paquete de R-cran y Matlab

Bibliografía básica:

- Buchholz, P.; Kriege, J. And Felko, I. (2014) Input Modeling with Phase-Type Distributions and Markov Models: Theory and Applications. Springer.
- Çinlar, E. (1975) Exceptional Paper—Markov Renewal Theory: A Survey. Management Science, 21, 7, 727-752.
- Hoyland, A. and Rausand, M. (1994) System Reliability Theory: models and statistical methods, John Wiley and Sons, New York.
- Kovalenko, I.N.; Kuznetsov N.Y. and Shurenkov, V.M. (1996) Models of Random Processes, CRC Press, Inc.
- Kulkarni, V.G. (1995) Modeling and Analysis of Stochastic Systems, Chapman & Hall. London.
- Kulkarni, V.G. (1999) Modeling, Analysis, Design, and Control of Stochastic Systems, Springer-

Verlag New York, Inc.

§ Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston.

§ Lisnianski, A. and Frenkel, I. (2012) Recent Advances in System Reliability. Signatures, Multi-state Systems and Statistical Inference. Springer-Verlag, London.

§ Lisnianski, A.; Frenkel, I. And Ding, Y. (2010) Multi-state System Reliability Analysis and Optimization for Engineers and Industrial Managers. Springer-Verlag London Limited.

§ Ross, S.M. (1983) Stochastic Processes. John Wiley & Sons. New York.

§ Ruiz-Castro, J.E. (2016) Complex multi-state systems modelled through Marked Markovian Arrival Processes. European Journal of Operational Research, 252, 3, 852-865.

§ Ruiz-Castro, J.E. (2016) Markov counting and reward processes for analyzing the performance of a complex system subject to random inspections. Reliability Engineering and System Safety, **145**, 155-168.

§ Ruiz-Castro, J.E. (2014) Preventive maintenance of a multi-state device subject to internal failure and damage due to external shocks, IEEE Transactions on Reliability, **63**, 2, 646-660.

§ Taylor, H.M. and Karlin, S. (1994) An Introduction to Stochastic Modeling, Academic Press.

Tijms, H.C. (2003) A First Course in Stochastic Models, John Wiley & Sons LTD, England

§ Buchholz, P.; Kriege, J. And Felko, I. (2014) Input Modeling with Phase-Type Distributions and Markov Models: Theory and Applications. Springer.

§ Çinlar, E. (1975) Exceptional Paper—Markov Renewal Theory: A Survey. Management Science, 21, 7, 727-752.

§ Hoyland, A. and Rausand, M. (1994) System Reliability Theory: models and statistical methods, John Wiley and Sons, New York.

§ Kovalenko, I.N.; Kuznetsov N.Y. and Shurenkov, V.M. (1996) Models of Random Processes, CRC Press, Inc.

§ Kulkarni, V.G. (1995) Modeling and Analysis of Stochastic Systems, Chapman & Hall. London.

§ Kulkarni, V.G. (1999) Modeling, Analysis, Design, and Control of Stochastic Systems, Springer-Verlag New York, Inc.

§ Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston.

§ Lisnianski, A. and Frenkel, I. (2012) Recent Advances in System Reliability. Signatures, Multi-state Systems and Statistical Inference. Springer-Verlag, London.

§ Lisnianski, A.; Frenkel, I. And Ding, Y. (2010) Multi-state System Reliability Analysis and Optimization for Engineers and Industrial Managers. Springer-Verlag London Limited.

§ Ross, S.M. (1983) Stochastic Processes. John Wiley & Sons. New York.

§ Ruiz-Castro, J.E. (2016) Complex multi-state systems modelled through Marked Markovian Arrival Processes. European Journal of Operational Research, 252, 3, 852-865.

§ Ruiz-Castro, J.E. (2016) Markov counting and reward processes for analyzing the performance of a complex system subject to random inspections. Reliability Engineering and System Safety, **145**, 155-168.

§ Ruiz-Castro, J.E. (2014) Preventive maintenance of a multi-state device subject to internal failure and damage due to external shocks, IEEE Transactions on Reliability, **63**, 2, 646-660.

§ Taylor, H.M. and Karlin, S. (1994) An Introduction to Stochastic Modeling, Academic Press.

Tijms, H.C. (2003) A First Course in Stochastic Models, John Wiley & Sons LTD, England

§ uchholz, P.; Kriege, J. And Felko, I. (2014) Input Modeling with Phase-Type Distributions and

Markov Models: Theory and Applications. Springer.

§ Çinlar, E. (1975) Exceptional Paper—Markov Renewal Theory: A Survey. Management Science, 21, 7, 727-752.

§ Hoyland, A. and Rausand, M. (1994) System Reliability Theory: models and statistical methods, John Wiley and Sons, New York.

§ Kovalenko, I.N.; Kuznetsov N.Y. and Shurenkov, V.M. (1996) Models of Random Processes, CRC Press, Inc.

§ Kulkarni, V.G. (1995) Modeling and Analysis of Stochastic Systems, Chapman & Hall. London.

§ Kulkarni, V.G. (1999) Modeling, Analysis, Design, and Control of Stochastic Systems, Springer-Verlag New York, Inc.

§ Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston.

§ Lisnianski, A. and Frenkel, I. (2012) Recent Advances in System Reliability. Signatures, Multi-state Systems and Statistical Inference. Springer-Verlag, London.

§ Lisnianski, A.; Frenkel, I. And Ding, Y. (2010) Multi-state System Reliability Analysis and Optimization for Engineers and Industrial Managers. Springer-Verlag London Limited.

§ Ross, S.M. (1983) Stochastic Processes. John Wiley & Sons. New York.

§ Ruiz-Castro, J.E. (2016) Complex multi-state systems modelled through Marked Markovian Arrival Processes. European Journal of Operational Research, 252, 3, 852-865.

§ Ruiz-Castro, J.E. (2016) Markov counting and reward processes for analyzing the performance of a complex system subject to random inspections. Reliability Engineering and System Safety, **145**, 155-168.

§ Ruiz-Castro, J.E. (2014) Preventive maintenance of a multi-state device subject to internal failure and damage due to external shocks, IEEE Transactions on Reliability, **63**, 2, 646-660.

§ Taylor, H.M. and Karlin, S. (1994) An Introduction to Stochastic Modeling, Academic Press.

Tijms, H.C. (2003) A First Course in Stochastic Models, John Wiley & Sons LTD, Englan Buchholz, P.; Kriege, J. And Felko, I. (2014) Input Modeling with Phase-Type Distributions and Markov Models: Theory and Applications. Springer.

- Çinlar, E. (1975) Exceptional Paper—Markov Renewal Theory: A Survey. Management Science, 21, 7, 727-752.
- Hoyland, A. and Rausand, M. (1994) System Reliability Theory: models and statistical methods, John Wiley and Sons, New York.
- Kovalenko, I.N.; Kuznetsov N.Y. and Shurenkov, V.M. (1996) Models of Random Processes, CRC Press, Inc
- Modeling and Analysis of Stochastic Systems, Chapman & Hall. London Kulkarni, V.G. (1995) Modeling and Analysis of Stochastic Systems, Chapman and Hall. London V.G. (1995) Modeling and Analysis of Stochastic Systems, Chapman & Hall. London
- Kulkarni, V.G. (1999) Modeling, Analysis, Design, and Control of Stochastic Systems, Springer-Verlag New York, Inc.
- Semi-Markov Processes and Reliability, Birkhäuser, Boston. Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston. Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston. Limnios, N. and Oprisan, G. (2001) Semi-Markov Processes and Reliability, Birkhäuser, Boston.
- Lisnianski, A. and Frenkel, I. (2012) Recent Advances in System Reliability. Signatures, Multi-state Systems and Statistical Inference. Springer-Verlag, London.
- Lisnianski, A.; Frenkel, I. And Ding, Y. (2010) Multi-state System Reliability Analysis and Optimization for Engineers and Industrial Managers. Springer-Verlag London Limited. Ross, S.M. (1983) Stochastic Processes. John Wiley & Sons. New York.

- Ruiz-Castro, J.E. and Zapata-Ceballos, H.A. (2026) Algorithmic analysis of a complex reliability system subject to multiple events with a preventive maintenance strategy and a Bernouilli vacation policy through MMAPs. Reliabiliy Engineering and System Safety, 111744.
- Ruiz-Castro, J.E. and Zapata-Ceballos, H.A. (2025) Algorithmic modelling of a complex redundant multi-state system subject to multiple events, preventive maintenance, loss of units and a multiple vacation policy through MMAP. Mathematics and Computers in Simulation, 230, 165-192.
- Ruiz-Castro, J.E. (2016) Complex multi-state systems modelled through Marked Markovian Arrival Processes. European Journal of Operational Research, 252, 3, 852-865.
- Ruiz-Castro, J.E. (2016) Markov counting and reward processes for analyzing the performance of a complex system subject to random inspections. Reliability Engineering and System Safety, **145**, 155-168.
- Ruiz-Castro, J.E. (2014) Preventive maintenance of a multi-state device subject to internal failure and damage due to external shocks, IEEE Transactions on Reliability, **63**, 2, 646-660.
- Taylor, H.M. and Karlin, S. (1994) An Introduction to Stochastic Modeling, Academic Press.
- Tijms, H.C. (2003) A First Course in Stochastic Models, John Wiley & Sons LTD, England

Recomendaciones y orientaciones para el estudiante:

Plazas: 1

2. DATOS DEL TUTOR/A:

Nombre y apellidos: JUAN ELOY RUIZ CASTRO

Ámbito de conocimiento/Departamento: ESTADÍSTICA E INVESTIGACIÓN OPERATIVA

Correo electrónico: jeloy@ugr.es

3. COTUTOR/A DE LA UGR (en su caso):

Nombre y apellidos:

Ámbito de conocimiento/Departamento:

Correo electrónico:

4. COTUTOR/A EXTERNO/A (en su caso):

Nombre y apellidos:

Correo electrónico:

Nombre de la empresa o institución:

Dirección postal:

Puesto del tutor en la empresa o institución:

Centro de convenio Externo:

5. DATOS DEL ESTUDIANTE:

Nombre y apellidos: YAGO VAZQUEZ SANCHEZ

Correo electrónico: yagovazquez@correo.ugr.es