**Abstract**
Multivariate response data abound in many applications including insurance, risk management, finance, health and environmental sciences. Data from these application areas have different dependence structures including features such as tail dependence. The dependence between random variables is completely described by their multivariate distribution. One may create multivariate distributions based on particular assumptions thus, limiting their use. For example, most existing multivariate distributions assume margins of the same form (e.g., Gaussian, Poisson, etc.) or limited dependence (e.g., tail independence, etc.). To solve this problem, copula functions (multivariate distributions with uniform margins on the unit interval) seem to be a promising solution. Copulas allow for flexible dependence modelling, different from assuming simple linear correlation structures and normality, which makes them well suited to the aforementioned application areas. In particular, the theory and application of copulas have become important in finance, insurance and other areas, in order to deal with dependence in the joint tails.

**Course Outcomes**
After the course, the participants will have a firm knowledge on the theory of copulas and the use of copulas for dependence modelling in finance, actuarial science and other areas. The course is worth 15 CPD hours.

**Target Audience**
The course is intended for actuarial practitioners, risk professionals, consultants and academics.

**Course Leader**
Aristidis K. Nikoloulopoulos is a Senior Lecturer in the School of Computing Sciences at the University of East Anglia. He completed his PhD at the Department of Statistics, Athens University of Economics and Business, in 2007 under the supervision of Prof. Prokisa. His PhD dissertation was ranked as excellent by world leading experts including the professors Harry Joe (University of British Columbia), and Roger B. Nelsen (Lewis & Clark College). After completing his PhD he had two postdoctoral positions. He worked with Professor Genest until the end of 2007 at the Laval University and then moved to the University of British Columbia to work with Professor Joe until July 2008. After completing his post-docs in Canada he had an adjunct lecturer position at Athens University of Economics and Business, lasting from November 2009 until August 2009. He has been appointed as a Lecturer in Statistics at the University of East Anglia in 2009 and in 2013 he was promoted to Senior Lecturer. His research is concerned with dependence modelling and development of multivariate copula models and inference procedures for non-normal multivariate response data. His work on copulas has appeared in leading journals in Statistics and he has been invited speaker to numerous international and major conferences, workshops, and seminars all over the world. He has also been invited to give copula courses in other international institutions such as the University of Sao Paulo (Brazil), the Polish Society of Actuaries and University of Warsaw.

**Dates:** 1st-3rd April, 2019

**Cost:** £860 + VAT

**Venue:** UEA Norwich

There is a 10% discount for UEA alumni, 30% discount for academics and 50% discount for postgraduate students.

**Monday, April 1**

9:30 An introduction to copulas for modelling continuous data: Parametric families-methods of inference

We will provide a survey of parametric families that are appropriate as models for multivariate continuous data with different dependence structures. Inferential procedures will be also discussed.

11:00 Coffee/Tea and Refreshments

11:30 Insurance company loss and expense application

The methods in the previous lecture are illustrated in the loss-ALAE data set in Frees and Valdez (1998). The data comprise general liability claims randomly chosen from late settlement lags and were provided by InsuranceServices Office, Inc. Each claim consists of an indemnity payment (the loss) and an allocated loss adjustment expense (ALAE). The objective is to describe the joint distribution of losses and expenses. Before that, we calculate some simple descriptive statistics and diagnostics to choose potential copula models.

13:00 Lunch

14:00 CopulaModel package by Joe and Krupskii

In this lecture we will illustrate the software CopulaModel for the analysis of the loss-ALAE data set in Frees and Valdez (1998). We will focus on (a) Implementation of the diagnostics for dependence and tail asymmetry, and (b) estimation of copula-based models. Before that, we will show that R is well-suited for programming your own maximum likelihood routines. Our focus will be the nlm command, which implements a quasi Newton algorithm for non-linear optimisation. Optimisation through nlm is relatively straightforward, since it is usually not necessary to provide analytic first and second derivatives.

16:00 Close

**Tuesday, April 2**

9:30 Vine copulas

Vine copulas have been applied recently for finance asset return and other data, see e.g. Kurowicka and Joe (2011). Vine copulas include multivariate normal and t copulas as special cases, but can also cover reflection asymmetry and have upper/lower tail dependence parameters being different for each bivariate margin. Joe et al. (2010) show that in order for a vine copula to have tail dependence for all bivariate marginals, it is only necessary for the bivariate copulas in level 1 to have tail dependence. Hence, for high-dimensional data, the number of dependence parameters can be reduced by considering truncated vines.

11:00 Coffee/Tea and Refreshments

11:30 CDVine package by Schepsmeier and Brechmann

In this session we will describe and illustrate the features of the R package CDVine by Schepsmeier and Brechmann (2011).

13:00 Lunch

14:00 Fitting vine copulas to financial return data

In this lecture we will use the software CDVine for the analysis of multivariate financial return data. Before proceeding to the vine copulas fitting via the CDVine package, we will implement diagnostics for dependence and reflection asymmetry to motivate the use of vine copulas with asymmetrical dependence for multivariate financial return data.

16:00 Close

**Wednesday, April 3**

9:30 Copula modelling for discrete data

For copula modelling with multivariate discrete data, we suggest models that admit a wide range of dependence, such as the multivariate normal (MVN) copula (Nikoloulopoulos, 2013a, 2013b, 2016). Given its wide range of dependence, MVN copula provides often the best fit or nearly the best fit for discrete data (Nikoloulopoulos et al., 2011). However MVN copula is inadequate to model multivariate data with refection asymmetry or tail dependence (Nikoloulopoulos et al., 2012). Vine copula constructions are suitable for modelling this kind of data since by using as bivariate blocks asymmetric bivariate copulas tail asymmetry can be accommodated, i.e., more probability in one or both joint tails can be obtained (Panagiotelis et al., 2012).

11:00 Coffee/Tea and Refreshments

11:30 Factor copula models

Factor models based on copulas are proposed for multivariate discrete data (Nikoloulopoulos and Joe, 2015). The factor copula models have interpretations of latent maxima/minima (in comparison with latent means) and can lead to more probability in the joint upper or lower tail compared with factor models based on the discretized multivariate normal distribution.

13:00 Lunch

14:00 Copula modelling for discrete in practice

This talk fits MVN, vine and factor copula models to real multivariate discrete response data in the R package CopulaModel (Joe and Krupskii, 2014).

16:00 Close