In the name of God

ADVANCED COURSE ON COMPUTATIONAL PHYSICS AND OPTIMIZATION

First midterm exam

(Time allowed: 3 hours)

Theoretical part

1. **Widely-used commands in terminal:**
   A: What is the command to connect a cluster? (assume that the valid IP is 192.168.220.100) (5 points)
   B: What is the command to copy a file from cluster to our local computer? (assume that the valid IP is 192.168.220.100) (5 points)
   C: What is the command to make a script as an executable file? (5 points)

2. **Central Limit Theorem:**
   A: At first clarify the statement of this theorem. (5 points)
   B: Then prove this theorem. (10 points)

3. **Correlation:**
   A: Deduce that for which type of data set, which correlation coefficients, namely Pearson or Spearman are more suitable? From the "Type" point of view in the different classes of the correlation, which type of correlation coefficients, Pearson or Spearman, are more suitable for "A" and "B" (Figure 1) (5 points)
   B: We are going to generate three time series. Is it possible to generate mentioned three data sets, whose covariance matrix are given by Cov_1 and Cov_2? Explain in details. (5 points)

$$Cov_1 \equiv \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & -1 \\ 1 & -1 & 1 \end{bmatrix}$$

$$Cov_2 \equiv \begin{bmatrix} 1 & -1 & -1 \\ -1 & 1 & 1 \\ -1 & 1 & 1 \end{bmatrix}$$
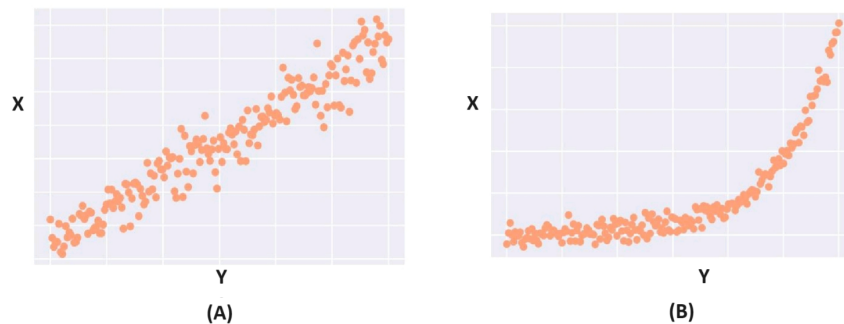

Figure 1: The illustration of he behavior of (y,x) for two cases, A and B.

4. **Explicit and Implicit methods:**
   For the following partial differential equation in a plane (y,x), compare the explicit and implicit numerical

methods.

$$\frac{\partial f(t,r)}{\partial t} = -\vartheta \nabla^2 f(t,r)$$

Suppose that $\vartheta > 0$, Which approaches would be proper for it? Why? (20 point)

Computational part

5. Generating series with an arbitrary PDF:
   A: Suppose that the following PDF is necessary for a simulation:

   $$p(s) = \frac{1}{5.4} \left(\frac{\cosh(s)}{(s+10)^2} + \tanh(s) \right)^2$$

   where $s \in [-4, +4]$. Generate a series of data including 1000 data points, whose PDF is given by the above PDF. Then check the validity of your results by computing the PDF of your generated data and comparing with the theoretical model. (10 points)
   B: Compute moments, $M_n(s)$, for $n = 3, 5$ and cumulants, $\mathcal{K}_n(s)$, for $n = 3, 4, 5$. (10 points)

6. Compute the un-weighted TPCF of the Peaks($\vartheta \geq 0.5\sigma$)-Trough($\vartheta \leq -0.5\sigma$) for (1+2)-Dimension data set (GN512.txt) Figure 2 by using the Natural estimator. According to the definition of exclusion zone, the radius of the exclusion zone is defined by: $1 + \Psi_{peak-trough}(r = R_{ex}, \vartheta) = \epsilon$ where $\epsilon \leq 0.01$. By plotting $1 + \Psi_{peak-trough}(r, \vartheta)$ as a function of r, determine the R_{ex}. (20 points)
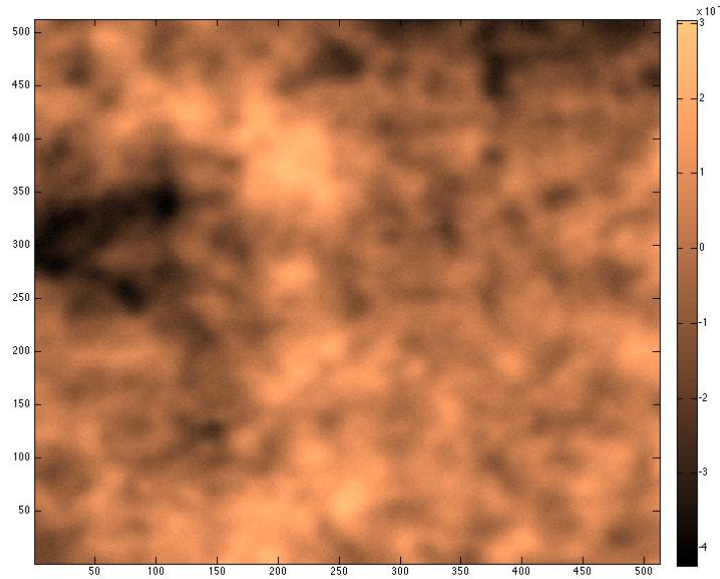

Figure 2: A typical $(1+2)$-dimensional data set.

Good luck, Movahed