ME2 Computing- Session 1: Revision of arrays, numerical discretisation and Graphics

Learning outcomes:

- Regain confidence with concepts of arrays and their implementation.
- Be able to choose appropriate array representation for scalar and vector field analysis.
- Get familiar with advanced graphics tools and techniques.

Before you start

In your H drive create a folder *H:\ME2MCP\Session1* and work within it.

Task A: Generate an array with a non-uniform range

1. Generate an array *x* of numbers in the range *[-5 : 5]* with the following steps:

$$\Delta x = 0.5 \text{ in } -5 \leq x \leq -2$$
$$\Delta x = 0.05 \text{ in } -2 < x < 3$$
$$\Delta x = 0.5 \text{ in } 3 \leq x \leq 5$$

2. Compute the functions: $f = \sin(x)$ and $g = \sin(x^2 + \pi)$

3. Plot, with scattered points, on the same graph, $f(x)$ and $g(x)$, with red diamond and purple circle seeds, respectively.

Task B: Multi-dimensional arrays and grids

1. Represent with appropriate variables the two functions:

$$f(x, y) = \sin x \cdot \cos y$$
$$g(x, y) = \cos x \cdot \sin y$$

in the range *x = [-2π : 2π]* and *y = [-π : 2π]* with steps $\Delta x = \Delta x = 0.1$.

2. Compute the two functions:

$$s(x, y) = f(x, y) + g(x, y)$$
$$p(x, y) = f(x, y) \cdot g(x, y)$$

Task C: Surface plots

1. Plot, both with a surface plot and a contour plot separately, the functions $s(x, y)$ and $p(x, y)$ of Task B.

2. Consider the function:
$$r(x, y, t) = f(x, y) \cdot e^{-0.5t}$$
in the same range of *x* and *y* as in Task B and *t = [0 : 10]* with Δt = 0.05.

3. Plot, with a surface plot, $r(x, y, t = 0)$ and $r(x, y, t = 5)$.

4. Plot the evolution along *t* of $r(x, y, t)$ at $x = \pi$ and $y = -\pi/2$.

Task D: Vector plots

Divergence and curl of vectors
From Maths tutorial Sheet 1 (Linda), problem 5:

$$\boldsymbol{f} = x\boldsymbol{i} + y\boldsymbol{j}$$

$$\boldsymbol{f} = y\boldsymbol{i} - x\boldsymbol{j}$$

1. Represent with appropriate variables the two vector fields $\boldsymbol{f}(x, y, z)$ in the range *x = y = [-5 : 5]* with intervals *dx = dy = 0.1*.

2. Plot as quivers and streamlines the two vector fields $\boldsymbol{f}$, and observe whether the fields are conservatives, irrotational, etc.

Helmholtz decomposition
From Maths tutorial Sheet 1 (Linda), problem 3:

The vector $\boldsymbol{u}(x, y) = \begin{pmatrix} 4x + 14y \\ -6x - 11y \end{pmatrix}$ can be decomposed into an irrotational component and an incompressible component.
Plot the two components and the overall vector $\boldsymbol{u}(x, y)$, within the same domain as above.

Task E: Advanced plotting

1. The two files *Maths.txt* and *Computing.txt* contain ME1 marks for the Maths and the Computing components, respectively. Read the two sets of data and round them to the nearest integer value.
Plot in two subplots: a) the distribution of Maths marks AND the distribution of Computing marks as bar plot, b) the scattered correlation of marks, i.e. Maths vs Computing marks.

2. Create a volumetric domain, with boundaries *x = [-2 : 2]*, *y = [-3 : 3]*, *z = [-π : 2π]* and nodal distances $\Delta x = \Delta y = \Delta z = 0.1$.
Evaluate the scalar function $f(x, y, z) = x^2 + y^2 + z^2 - 5sin^2 z$
Plot the function $f(x, y, z)$ with iso-surfaces.

Task F: *Bonus (a bit challenging)* ***Slicing with conditions***

1. Compute, with vectorised operations, the value:

$$ym(x) = |y(x)| = |\sin{(x)}|$$

in the range *x = [-5 : 5]* with *dx = 0.1*.

2. Compose the array *ymsat* such that:

$$\begin{cases} ymsat = 0 & \text{for} - 5 \leq x \leq 0 \\ ymsat = ym & \text{for } x > 0 \text{ and } ym \leq 0.5 \\ ymsat = 0.5 & \text{for } x > 0 \text{ and } ym > 0.5 \end{cases}$$