

# Assignment 1 : CS-E4830 Kernel Methods in Machine Learning 2019

The **deadline** for this assignment is **Thursday 31.01.2019 at 4pm**. If you have **questions** about the assignment, you can ask them in the 'General discussion' section on MyCourses. We will have a tutorial session regarding the **solutions** of this assignment on 31.01.19 at 4:15 pm in TU1(1017), TUAS, Maarintie 8. The solutions will also be available in MyCourses.

Please follow the **submission instructions** given in MyCourses: <https://mycourses.aalto.fi/course/view.php?id=20602&section=2>.

## Pen & Paper exercise

### Kernel Computation

**Question 1** (5 points): Recall from the Lecture 1, the general form for the polynomial kernel

$$K(x, y) = (\langle x, y \rangle + c)^m$$

where  $c \geq 0$ ,  $m$  is a positive integer and  $x, y \in \mathbb{R}^d$ .

- (2 points) Prove that  $K(x, y)$  as defined above is a valid kernel by using (i) Product of kernel function is a kernel function, and (ii) Conic sum of kernels is a kernel. (Hint : Use Binomial Theorem)
- (3 points) For the special case  $x, y \in \mathbb{R}^2$ ,  $c = 0$ , and  $m = 3$ , when  $K(x, y) = (\langle x, y \rangle)^3$ , write down the feature space expansion of feature map  $\phi(x)$  and  $\phi(y)$  such that  $K(x, y) = \langle \phi(x), \phi(y) \rangle$ , by taking order of feature into account, i.e., for instance,  $x_1 x_2 x_3$  is considered different from  $x_3 x_2 x_1$ , and so on.

## Computer Exercise

Solve the computer exercise in JupyterHub (<https://jupyter.cs.aalto.fi>). The instructions for that are given in MyCourses: <https://mycourses.aalto.fi/course/view.php?id=20602&section=3>.