MAN AGAINST MACHINE: EXPERIMENTS IN VEGETATION INDUCED RESISTANCE

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Proper modelling of flow in wetlands and vegetated floodplains is of great practical importance. Both analytical and experimental studies of vegetation-related resistance to flow and the equivalent resistance coefficients have shown that the resistance coefficients are water-depth dependent. Consequently, the traditional approach of using a single resistance coefficient fails to correctly describe the physics of the phenomenon. One way of improving upon this description is updating the equivalent resistance coefficient based on the computed water depth. In order to do so, a relationship between vegetation characteristics, bed resistance, water depth and equivalent resistance coefficient is needed. Two main approaches for creating such a relationship are contrasted. The first approach is the time-honoured method where a scientist uses whatever knowledge is available on the physics about the phenomenon and assembles an equation based on detailed understanding of the phenomena involved in the process. This understanding takes the form of many small models of sub-phenomena that are assembled to create an overall equation. The second approach employs a genetic programming technique to induce a set of relationships that are subsequently selected and improved by a scientist.

Testing expressions for their ability to model a phenomenon such as resistance induced by vegetation requires experimental data. Obtaining observations for vegetation-induced roughness at fine resolution is prohibitive in terms of effort and cost. Therefore, in present work we use dynamical 1DV model of the turbulence to generate data. Such a dynamical model employs all available knowledge about characteristics of plants, turbulence induced by the plants, and resistance caused by the drag forces on the plants. Obtaining real-world values of the resistance coefficients from this microscopic model is trivial, however, a compact expression describing the phenomenon is not available. In addition to synthetic data, in order to ultimately test the models created here, a dataset of 177 laboratory flume experiments was collected from 10 independent studies. This data is not used for training, but kept aside to validate the equations induced.

Un-submerged flow conditions can be successfully treated analytically. Essentially, based on balance of horizontal momentum in uniform steady flow conditions the following equation can be obtained:

$$C_r = \sqrt{\frac{2g}{C_D mDh}} \qquad (0.1)$$

Two different methods for treatment of submerged vegetation were derived by Baptist (2004), namely the "method of effective water depth" which resulted in:

$$C_r = \frac{d\sqrt{\dfrac{gh\left(1-A_p\dfrac{k}{h}\right)-\dfrac{C_D mD(h-k)(k-d)}{2(1-A_p)\kappa^2}\left[\left\{\ln\left(\dfrac{30(k-d)}{k_v}\right)\right\}^2-2\ln\left(\dfrac{30(k-d)}{k_v}\right)+2\right]}{\dfrac{g}{(1-A_p)C_b^2}+\dfrac{C_D mDd}{2(1-A_p)}}}+(h-d)^{\frac{3}{2}}18\log\left(1+\dfrac{12(h-d)}{k_v}\right)}{h\sqrt{h}} \tag{0.2}$$

and the method utilising an analytical formula derived from the momentum balance:

$$C_r = \frac{k\sqrt{\dfrac{gh\left(1-A_p\dfrac{k}{h}\right)}{\dfrac{g}{(1-A_p)C_b^2}+\dfrac{C_D mDk}{2(1-A_p)}}}+(h-k)^{\frac{3}{2}}18\log\left(1+\dfrac{12(h-k)}{k_v}\right)}{h\sqrt{h}} \tag{0.3}$$

By comparison, genetic programming, an evolutionary computing technique that can be used to find the symbolic form of an equation is applied to the same set of data. Genetic programming results provided a dimensionally consistent formula that had both smallest RMSE and the highest CoD:

$$\frac{C_r}{\sqrt{g}} = \sqrt{\frac{2}{c_D mDk}} + \ln\left\{\left(\frac{h}{k}\right)^2\right\} \tag{0.4}$$

After some modification the formula was altered to:

$$C_r = (1-A_p)\sqrt{\frac{1}{\dfrac{1}{C_b^2}+\dfrac{1}{2g}C_D mDh}} + \frac{\sqrt{g}}{\kappa}\ln\left(\frac{h}{k}\right) \tag{0.5}$$

These changes provided better fitting as well as provided theoretically more sound coefficient in the logarithmic term. Although fractionally more complicated than the original formulation, modified expression was found to be in good agreement with the data, especially in regions with higher Chézy values. The formulation was significantly more accurate than those generated by scientist. Furthermore, it is theoretically well founded, combining the (known) resistance for the flow inside the vegetation with the observed logarithmic profile above the vegetation.