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*B. Tuning the COCOMO*

Although many algorithmic models are usually not very accurate, they reflect a lot of useful expert knowledge in this field. In order to make the best use of this kind of expert knowledge, it is worthwhile to integrate the algorithmic model into the present neural network model. Calibrating the parameters of algorithmic models is usually is very challenging task. In the current neural network model, parameters of the algorithmic model are adjusted through learning. The initial definition of the COCOMO II model and its results are provided in [2]. The initial COCOMO II model had the following form:

$$Effort = A \times [Size]^{1.01+\sum_{i=1}^{5} SF_i} \times \prod_{i=1}^{17} EM_i \quad (1)$$

where, A is the multiplicative constant, Size of the software project measured in terms of KSLOC, SF is the Scale Factors and EM is the Effort Multipliers. The COCOMO Model shown in "(1)," is a non linear model. To solve this problem we transform the non-linear model of "(1)," into a linear model using the logarithms to the base e, is shown as follows in "(2)".

$$\ln(PM) = \ln A + \ln(EM_1) + \ln(EM_2) + \ldots + \ln(EM_{17}) + [1.01+SF_1+\ldots+SF_5]*\ln(Size) \quad (2)$$

The above equation has the form of the model below:

$$O_{est} = \overbrace{[b_1 + u_1*I_1 + u_2*I_2 + \ldots u_{17}*I_{17}]}^{\text{Part 1}} + \underbrace{[b_2 + I_{18}+\ldots+ I_{22}]*[v_i + \ln(size)]}_{\text{Part 2}} \quad (3)$$

where
$O_{est} = \ln(PM)$;
$I_1 = \ln(EM_1)$ ;……; $I_{17} = \ln(EM_{17})$;
$I_{18} = SF_1$ ; ….. ; $I_{22} = SF_5$;

$b_1$ and $b_2$ are the biases and the coefficients $u_i$, $v_i$ are the additional terms introduced in the model, which are to be estimated as follows. Initially we assume that the values of the coefficients are to be 1 for $u_i$ and 0 for $v_i$ to estimate the output $O_{est}$. Then this estimated effort is compared with that of the actual observed effort in the log space. The difference is the error in the estimation, which should be minimized. All the model's parameters are assumed to be responsible for the output error [5]. The difference in this estimation is propagated to the inputs for adjusting the coefficients, so that this knowledge can be incorporated in to the model in the form of coefficients. Thus these coefficients of the model can be estimated by the proposed neural network as discussed below. Note that part 1 of "(3)," deals with effort multipliers, which represents the upper section of the neural network under study and part 2 deals with scale factors that represents the lower section.

*C. Architecture of the NN Model*

This paper proposes a new architecture with multi layer feed forward neural network and is constructed to accommodate the COCOMO II model, to overcome the limitations which were identified in the previous section. The proposed model improves the performance of the network and the accuracy of the estimation in predicting the effort. The use of the proposed neural network to estimate ln(PM) (Person months in logs) in the "(2)," requires 22 input nodes in the input layer that corresponds to all EM, SF and it has two bias values. The proposed network consists of two hidden layers nodes $H_{EM}$ and $H_{SF}$ that take into account the contribution of Effort Multipliers and Scale Factors separately as shown in "Fig. 1."

All the inputs are normalized to speed up the training process of the network, as it is already proved that the neural networks work better if inputs and outputs lie between 0 and 1 [20]. However, in order to structure the network to accomplish the COCOMO II model with multi layer feed forward neural network, some pre-processing of data for the input layer is considered.

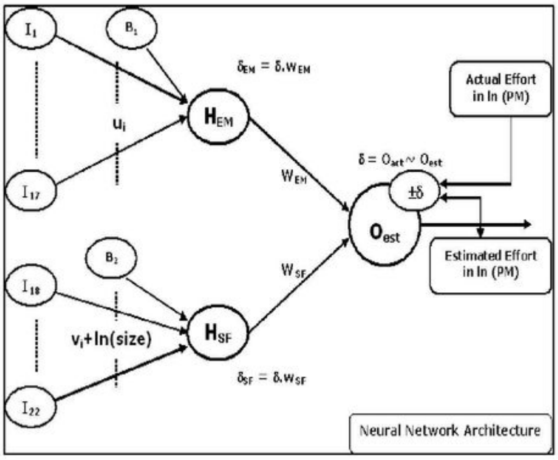


**Figure 1. Architecture of the proposed neural network model**

Note that in the above network, all the input values $I_1$ to $I_{22}$ are pre-processed according to the model defined in "(3)". The size of the product in KSLOC is not considered as one of the inputs to the network but considered as a cofactor for the weights for the scale factors. To overcome the draw backs associated with sigmoidal functions and to accomplish the effort in ln person months, identity function is used at the input, hidden and output units. The weights associated with each input nodes connected to the hidden layers are denoted by $u_i$ for each input ln ($EM_i$) for $1 \leq i \leq 17$ and for $B_1$. On the other hand, the weights associated with each $SF_i$ input nodes to the hidden layer are $v_i + \ln(size)$ for $18 \leq i \leq 22$ and the bias denoted by $B_2$. The weights associated with each hidden layer nodes connected to the output layer are denoted by $w_{EM}$ and $w_{SF}$. The process of establishing a neural network involves, initializing the





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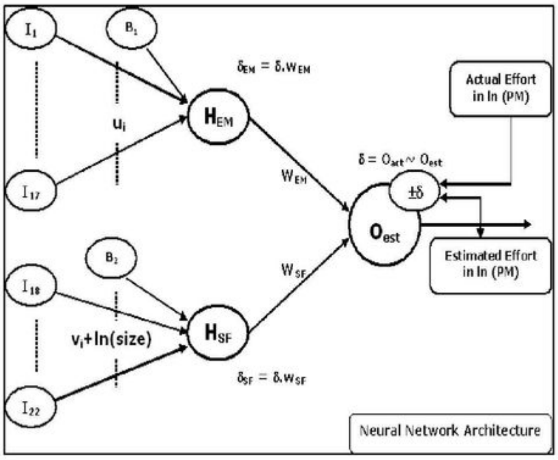


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