PERFORMANCE EVALUATION OF NEURAL NETWORK ARCHITECTURES FOR THE MULTIVARIATE ANALYSIS OF GAS COMPOSITIONS AND THE PREDICTION OF GEOTHERMAL RESERVOIR TEMPERATURES

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The prediction of deep equilibrium temperatures in geothermal systems is an important task required for the evaluation of their stored energy resources. Solute and gas geothermometers are geochemical tools commonly used for estimating reservoir temperatures under exploration and exploitation. Solute geothermometers are generally recommended for predicting temperatures of liquid-dominated geothermal systems, whereas gas geothermometers are better suggested for vapor-dominated systems. Gas geothermometers have been developed from both fluid chemistry databases and thermodynamic analysis of complex water-rock-gas reactions present in geothermal environments. Geochemical studies have demonstrated that the gas compositions (CO\textsubscript{2}, H\textsubscript{2}S, NH\textsubscript{3}, H\textsubscript{2}, Ar, N\textsubscript{2}, CH\textsubscript{4}, and others) or gas ratios (CO\textsubscript{2}/H\textsubscript{2}, H\textsubscript{2}S/H\textsubscript{2}, CH\textsubscript{4}/CO\textsubscript{2}, H\textsubscript{2}S/CO\textsubscript{2} and others) usually present in geothermal discharges are controlled by temperature dependent equilibria processes among alteration minerals of the host reservoir rock.

Up to date, a plethora number of gas geothermometers have been developed based upon the analysis of gas compositions and thermodynamic equations under the assumption of theoretical equilibrium conditions. However, most of the reservoir temperature estimates inferred from these geothermometers have shown significant discrepancies when they are compared with borehole temperature measurements. These discrepancies are mainly due to several uncertainty sources such as: the geochemical parameters that affect the equilibrium constants of the gas reactions, the gas partition coefficients, the geothermometer calibration, the regression coefficient statistical errors, and the gas sampling and analysis errors. Considering such problems, the
development of improved and reliable gas geothermometers is still required for the geothermal industry. Bivariate and multivariate statistical techniques have been historically used for studying the geochemical relationships among the gas compositions and the bottomhole temperatures (BHT) of geothermal wells.

In the present study, artificial neural network (ANN) architectures were used to perform a multivariate analysis among the gas compositions and BHT. Several ANN architectures were evaluated using a world geochemical database containing around 536 data sets of gas chemical compositions (CO₂, H₂S, CH₄, and H₂) and BHT measurements (collected from world-wide geothermal wells). Gas compositions (dry-basis, mmol/mol) were considered as main input data, whereas BHT measurements were defined as the output target. The effect of the input data treatment together with some complex computational structures was used for the learning performance evaluation of the ANN to predict the geothermal reservoir temperatures with confidence.

The Levenberg-Marquardt learning algorithm, the hyperbolic tangent sigmoid, and the linear transfer functions were used for optimizing the ANN architectures. The best ANN architectures were selected taking into account the highest correlation coefficients between the measured and predicted temperatures using conventional statistical criteria and acceptable confidence levels. Finally, the best ANN architectures were successfully validated using a random geochemical database (n= 107) for avoiding bias errors. Details of the computational methodology, numerical validation, statistical analysis, and a preliminary application of the improved geothermometer in geothermal wells are described in the present work.