CISE 301 Term: 122

Computer Assignment 2

Instructions:

- **This assignment contains two parts**
- **Both parts are required**
- **Submit soft and hard copies by Monday 6th May 2013, by the end of the lecture**

I. Predicting Gas Solubility using Multiple Regression Models

This project is about predicting gas solubility using multiple regression models.

Gas solubility (R_s) is a measure of the capability of oil to dissolve gas. It is in nature the result of complicated molecular interactions between all the individual components existing in oil and associated gas. But it is usually experimentally determined in the laboratory. Regardless of the specific lab experiments that are usually requested for a reservoir, one can find well-known correlations for this purpose in the literature. It is suggested here to use Multiple regression models to predict this property.

Multiple regression analysis attempts to explain the relationships between the independent variables and the dependent variable. When there are p the independent variables $X_1, X_2, ..., X_p$, the multiple exponential regression equation is the general form as follows: $Y_i = \beta_0 X_1^{\beta 1} X_2^{\beta 2} ... X_p^{\beta p}$

Where Y is a dependent variable; $X_1, X_2, ..., X_p$ are the independent variables; β_0 is the constant that the regression line intercepts the Y axis, representing the amount the dependent Y will be when all the explanatory variables are 0, and β_i $1 \le i \le p$ are the regression coefficient, representing the amount the response variable Y changes when the explanatory variable changes. Using the dataset provided below, write a program code to indentify the following models suggested for gas solubility and saturated viscosity

Perform the following functions for predicting gas solubility

Model G1

$$R_s = \gamma_g \left(\left(\frac{P_b}{18.2} + 1.4 \right) 10^x \right)^{1.2048}$$

$$x = a_1 API - a_2 (T - 460)$$

Determine Coefficients a_1 and a_2

Model G2 The following is another suggested model for gas solubility is suggested:

$$R_s = \left[\left(\frac{P_b}{112.727} + 12.340 \right) \gamma_g^{0.8439} \; 10^x \right]^{1.73184}$$

$$x = b_1 (10^{-4}) API^{1.5410} - b_2 (10^{-5})(T - 460)^{1.3911}$$

Determine Coefficients b_1 and b_2

Model G3 Other reliable and meaningful regression equations that could be obtained by the statistical analysis are given as:

$$R_s = b P_b^{1.014} \gamma_g^{0.719} T^{-0.223} API^{1.182} \qquad (3)$$

Determine Coefficients *b*

Which of the models G1, G2, G3 is the best? Justify your answer

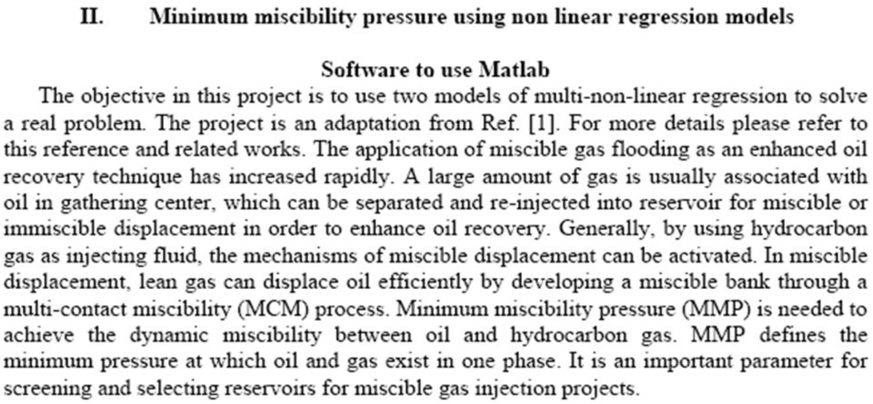
For your calculations, use the following dataset.

	P_b	temp	R_s	γ_g	γ_o	API
1	400	219	123	0.835	0.8104	43.1

2	550	211	145	0.897	0.8139	42.4
3	650	290	251	0.755	0.6524	85.4
4	795	219	248	0.887	0.7903	47.5
5	855	200	223	0.722	0.7742	51.3
6	985	200	264	0.712	0.7733	51.5
7	1300	203	426	0.786	0.7592	54.9
8	1450	237	699	0.827	0.6584	83.4
9	1900	172	414	0.68	0.8134	42.5
10	2415	220	464	0.836	0.847	35.6
11	3000	185	811	0.812	0.842	36.6
12	4200	200	891	0.975	0.887	28.0

Nomenclature:

API: American Petroleum Institute Index for oil gravity
P: Pressure, psia
P_b: Bubble point pressure, psia
R_s: Gas solubility or gas oil ratio [Standard cubic foot per standard condition barrel] SCF/STB
SC: Ambient Standard Conditions In Terms Of Temperature and Pressure
T: Temperature ºF
V_o: Oil Volume
w: Connection Weight
γ_o: Oil Gravity
γ_g: Gas Gravity
μ_{od}: Dead Oil Viscosity
μ_{od}: Saturated Oil Viscosity
b: Bubble Point
g: Gas
o: Oil



II. Minimum miscibility pressure using non linear regression models

Software to use Matlab

The objective in this project is to use two models of multi-non-linear regression to solve a real problem. The project is an adaptation from Ref. [1]. For more details please refer to this reference and related works. The application of miscible gas flooding as an enhanced oil recovery technique has increased rapidly. A large amount of gas is usually associated with oil in gathering center, which can be separated and re-injected into reservoir for miscible or immiscible displacement in order to enhance oil recovery. Generally, by using hydrocarbon gas as injecting fluid, the mechanisms of miscible displacement can be activated. In miscible displacement, lean gas can displace oil efficiently by developing a miscible bank through a multi-contact miscibility (MCM) process. Minimum miscibility pressure (MMP) is needed to achieve the dynamic miscibility between oil and hydrocarbon gas. MMP defines the minimum pressure at which oil and gas exist in one phase. It is an important parameter for screening and selecting reservoirs for miscible gas injection projects.

The objective here is to compare three following regression models:

1)-

Glaco (1985) Correlation:

$$MMP(CO_2) = \begin{cases} a_0 - 3.404M_{C_{7+}} + 1.7 \times 10^{-9} M_{C_{7+}}^{3.73} \exp\left(a_1 M_{C_{7+}}^{-1.058}\right) T & ,x_{C_2-C_6} > 18\% \\ a_2 - 3.404M_{C_{7+}} + 1.7 \times 10^{-9} M_{C_{7+}}^{3.73} \exp\left(a_3 M_{C_{7+}}^{-1.058}\right) T - 121.2x_{C_2-C_6} & ,x_{C_2-C_6} < 18\% \end{cases}$$

2)-

Yuan et al.(2005) Correlation:

$$MMP(CO_2) = a_0 + 6.612M_{C_{7+}} - 44.979x_{C_2-C_6} + \left(a_1 + 0.11667M_{C_{7+}} + 8166.1\frac{x_{C_2-C_6}}{M_{C_{7+}}^2}\right)T$$

$$+(-a_2 + 0.0012283M_{C_{7+}} - 4.0152 \times 10^{-6} M_{C_{7+}}^2 - a_3 \times 10^{-4} x_{C_2-C_6})T^2$$

3)-

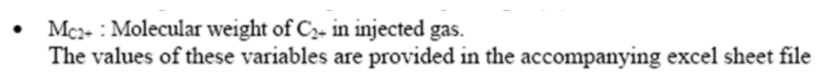
$$MMP = 43.664 - 4.542\alpha + 0.689\alpha^2 - 0.132\beta$$

$$\alpha = \frac{x_{c2-c6}^{1.72785} \times x_{c1}^{.1}}{(1.8T + 32)^{.5} \times M_{c7+}}$$

$$\beta = Y_{c2+}^{(a_1 + a_2 M_{c2+})}$$

Where

- MMP: Minimum Miscibility Pressure (MPa)
- XC_{2-6} : Intermediate composition in the oil containing $C_{2-6}, C0_2$ and H_2S in mole %
- XC_1 : Amount of methane in the oil (%)
- T: Temperature ($°C$)
- $M_{C_{7+}}$: Molecular weight of C_{7+} (g/mol)
- $Y_{C_{2+}}$: Molecular weight of C_{2+} in injected gas



- M_{C2+} : Molecular weight of C_{2+} in injected gas.
  The values of these variables are provided in the accompanying excel sheet file

Question 1: Using the material covered in the course perform a linearization transformation and determine the values of the coefficients a_i

Question 2: Calculate the error in the sense of least square when using the three models with the values of a_i calculated in Question 1

Using other regression models to predict the MMP gave the results in the ninth column of table below.

Question 3: Compare your results from Q2 with the result of other regression model, which of the models is more accurate? Justify your answer.

For further reading on the problem see reference

Maklavani, A. M.a; 1Moradi, B.b; Tangsirifard, J11 NEW MINIMUM MISCIBILITY PRESSURE (MMP) CORRELATION FOR HYDROCARBON MISCIBLE INJECTIONS, BRAZILIAN JOURNAL OF PETROLEUM AND GAS |V.4 N.1|P.011-018|2010

Table 1. Reservoir oil and injection gas properties and MMP data.

C1 %	C_2-C_4 %	MWC_{5+}	T / °C	C_{2+}	MWC_{2+}	Exp MMP(MPa)	Reference	calc MMP(MPa)
55	22	209	98.33	14	37.25	39.990	Firoozabadi and Aziz, 1986	38.871
50	22	250	121.11	10	33.51	41.369	Firoozabadi and Aziz, 1986	40.682
49	23	250	121.11	0	0	43.437	Firoozabadi and Aziz, 1986	43.321
57	26	183.6	84.22	0	0	43.437	Firoozabadi and Aziz, 1986	43.114
55	22	209	98.33	16	37.71	39.990	Firoozabadi and Aziz, 1986	37.994
50	23	250	121.11	10	34.01	41.369	Firoozabadi and Aziz, 1986	40.632
49	23	250	121.11	0	0	43.437	Firoozabadi and Aziz, 1986	43.321
46	25	240.68	115.93	18	39.77	37.235	Michelsen and Stenby, 1998	36.875
42	1	302	150.00	35	44.1	26.752	Kuo, 1985	26.551
42	1	302	150.00	38	44.1	25.166	Kuo, 1985	24.516
42	1	302	150.00	46	44.1	18.961	Kuo, 1985	18.804
33	24	215	101.67	47	39.91	16.547	Kuo, 1985	20.199
33	24	215	101.67	47	39.91	18.478	Kuo, 1985	20.249
39	27	258	125.56	24	38.19	33.274	NIOC, 1998	34.120
31	27	271	132.78	23	37.34	32.922	NIOC, 1998	34.859
37	25	294.97	146.09	23	37.34	34.474	Arya et al., 2001	34.943
31	27	271	132.78	23	37.34	32.922	Arya et al., 2001	34.859
44	31	231	110.56	27	38.73	35.954	Glass, 1985	32.305
33	26	121.91	49.95	15	37.37	36.051	Wang and Orr, 2000	37.943
23	33	141.74	60.97	41	41.86	22.201	Jean-Noel et al., 2001	22.397
24	30	141.99	61.11	41	41.86	23.601	Jean-Noel et al., 2001	22.559
54	24	132.12	55.62	17	39.77	38.001	Jean-Noel et al., 2001	37.019
22.92	32.08	257.7	125.39	41.47	42	22.105	Jean-Noel et al., 2001	22.573
23.64	30.36	254.4	123.56	41.47	42	23.504	Jean-Noel et al., 2001	22.614
45.85	24.68	143.7	62.06	18.12	39.89	37.611	Jean-Noel et al., 2001	36.517
26.57	30.25	245.43	118.57	12	39.43	36.611	Jean-Noel et al., 2001	39.428
54.26	24.12	238.15	114.53	17.88	40	37.907	Jean-Noel et al., 2001	36.903
6	28	175	79.44	43	41.34	24.580	Pedrood, 1995	21.944