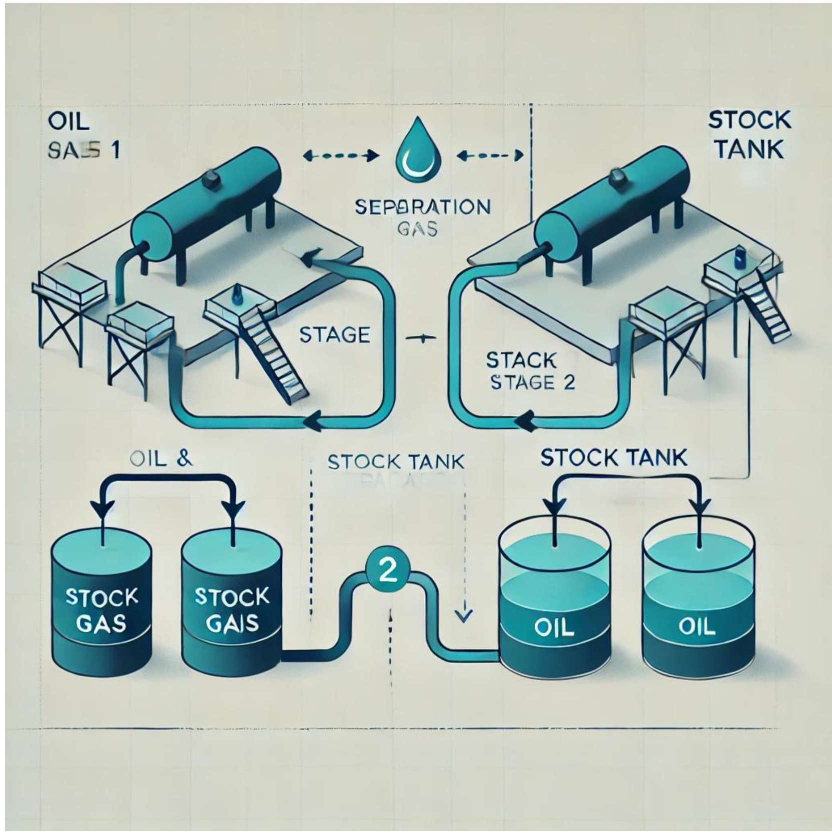
Automating DLE Correction for Reservoir Engineering: A Python-Based Approach to Enhance PVT Data Accuracy



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Introduction to DLE Correction

Definition:

- DLE (Differential Liberation Experiment) measures oil properties (Bo, Rs) under reservoir conditions.
- Correction adjusts DLE data to match field separator conditions.

Objective:

- Align lab data with actual production conditions for accurate reservoir analysis.

Importance:

- Critical for material balance, reservoir simulation, and production forecasting.

Why Perform DLE Correction?

Consistency:

- Lab DLE data (reservoir conditions) differs from field separator conditions.
- Correction ensures data consistency for field applications.

Accuracy:

- Improves reliability of Bo (oil formation volume factor) and Rs (solution gas-oil ratio).
- Enhances reserve estimation and recovery predictions.

Practical Impact:

- Optimizes production strategies.
- Reduces errors in field development planning.

Overview of the DLE Correction Script

Purpose:

- Automates DLE correction using CCE and Separator Test data.

Key Components:

- Global variables for data validation.
- Data import and parsing functions.
- Correction functions for calculations.
- Main function for workflow and visualization.

Libraries Used:

- NumPy, Pandas, Plotly, Openpyxl for data processing, plotting and Excel export.

Defining Expected Headers

Variable: EXPECTED_HEADERS

Purpose:

- Defines required column headers for each dataset.

```
EXPECTED_HEADERS = {
    "CCE Experiment": ["Pressure (psia)", "Relative Volume (V/Vb)"],
    "DLE Experiment": ["Pressure (psia)", "Bo (RB/STB)", "Rs (scf/stb)"],
    "Separator Test": ["Separator Pressure (psia)", "Separator Temperature (degF)",
                       "GOR (Rsfb) (scf/stb)", "Bofb (RB/STB)"]
}
```

Details:

- CCE Experiment: 2 columns (Pressure (psia), Relative Volume (V/Vb)).
- DLE Experiment: 3 columns (Pressure (psia), Bo (RB/STB), Rs (scf/stb)).
- Separator Test: 4 columns (Separator Pressure (psia), Separator Temperature (degF), GOR (Rsfb) (scf/stb), Bofb (RB/STB))

Benefit:

- Ensures data consistency for CSV file imports.

Data Import – File Path Validation

Variable: get_valid_file_path

Purpose:

- Ensures user-provided file paths for CSV files are valid.

Process:

- Prompts user for file paths (e.g., ./cce_data.csv).
- Validates that the file exists using os.path.isfile.
- Loops until a valid path is provided.

Benefit:

- Prevents runtime errors due to missing or invalid files.

```python
import os

def get_valid_file_path(prompt):
    while True:
        path = input(prompt)
        if os.path.isfile(path):
            return path
        print(f"Error: File '{path}' does not exist. Please enter a valid file path.")
# Get valid file paths with user prompts
print("Please enter the paths to your CSV files:")
cce_data_path = get_valid_file_path("Enter path to CCE data CSV file (e.g., './cce_data.csv'): ")
dle_data_path = get_valid_file_path("Enter path to DLE data CSV file (e.g., './dle_data.csv'): ")
sep_data_path = get_valid_file_path("Enter path to Separator data CSV file (e.g., './sep_data.csv'): ")
```

Data Import – Import and Validate

Variable: import_and_validate_data

Purpose:

- Imports CCE, DLE, and Separator Test data from CSV files.

Process:

- Uses pd.read_csv to load data from user-provided file paths.
- Raises errors if files cannot be imported.
- Prints imported DataFrames for user verification.

Benefit:

- Simplifies data input by using CSV files.

Data Import – File-Based Input

Input Method:

- Users provide paths to CSV files for CCE, DLE, and Separator Test data.

Example File Structure:

- CCE : Pressure (psia), Relative Volume (V/Vb)
- DLE : Pressure (psia), Bo (RB/STB), Rs (scf/stb)
- Separator Test: Separator Pressure (psia), Separator Temperature (degF), GOR (Rsfb) (scf/stb), Bofb (RB/STB)

Benefit:

- Easier to manage large datasets.

Data Import – User Prompting

Purpose:

- Prompts user to enter file paths for CCE, DLE, and Separator Test CSV files

Example Prompt:

- "Enter path to CCE data CSV file (e.g., './cce_data.csv'):"

Error Handling:

- Validates file existence and prompts again if the files are not found.

Benefit:

- Guides users to provide correct file paths.
- Ensures smooth data import process

Correction Functions - Bubble Point Validation

Function

validate_bubble_point

Purpose:

- Ensures the bubble-point pressure (pb) is a valid number.

Process:

- Prompts user for input.
- Validates input as a float or integer.
- Loops until a valid value is provided.

```python
def validate_bubble_point():
    while True:
        try:
            pb = float(input("Enter the bubble-point pressure (psia, integer or float): "))
            return pb
        except ValueError:
            print("Error: Bubble-point pressure must be a number. Try again.")
```

Example

For Well AB: pb = 1662 psia.

Correction Functions – DLE Correction Logic

Function

correct_dle_to_separator

Inputs:

- DLE data: pressures, bo_dle, rs_dle.
- CCE data: vrel (relative volume).
- Separator data: bofb, rsfb.
- Bubble-point pressure: pb.

Key Steps:

- Finds bubble-point index in DLE data.
- Computes Sod = Bo/Bodb (Bo at bubble-point).

Output:

- Corrected Bo and Rs values.

```python
def correct_dle_to_separator(pressures, bo_dle, rs_dle, vrel, pb, rsfb, bofb):
    """
    Corrects DLE data to separator conditions.
    Uses the bubble-point pressure and the optimum separator condition (Bofb, Rsfb)
    to compute corrected DLE Bo and Rs.
    """
    pb_idx = np.where(np.isclose(pressures, pb, atol=1e-2))[0]
    if len(pb_idx) == 0:
        raise ValueError(f"Bubble-point pressure {pb} not found in DLE pressure data: {pressures}")
    pb_idx = pb_idx[0]
    bodb = bo_dle[pb_idx]    # Bo at bubble-point
    rsds = rs_dle[pb_idx]    # Rs at bubble-point
    sod = bo_dle / bodb
    bo_corrected = np.zeros_like(bo_dle)
    for i, p in enumerate(pressures):
        if p >= pb:
            bo_corrected[i] = vrel[i] * bofb
        else:
            bo_corrected[i] = bofb * sod[i]
    rs_corrected = np.zeros_like(rs_dle)
    for i, p in enumerate(pressures):
        if p >= pb:
            rs_corrected[i] = rsfb
        else:
            rs_corrected[i] = rsfb - (rsds - rs_dle[i]) * (bofb / bodb)
    return bo_corrected, rs_corrected
```

Correction Calculations – Bo Correction

Logic:

- Above bubble-point (p >= pb):

  Bo_corrected = Vrel * Bofb.

  Uses CCE relative volume to scale Bofb.

- Below bubble-point (p < pb):

  Bo_corrected = Bofb * Sod.

  Sod = Bo/Bodb (ratio of Bo to Bo at bubble-point).

```
def correct_dle_to_separator(pressures, bo_dle, rs_dle, vrel, pb, rsfb, bofb):
    """
    Corrects DLE data to separator conditions.
    Uses the bubble-point pressure and the optimum separator condition (Bofb, Rsfb)
    to compute corrected DLE Bo and Rs.
    """
    pb_idx = np.where(np.isclose(pressures, pb, atol=1e-2))[0]
    if len(pb_idx) == 0:
        raise ValueError(f"Bubble-point pressure {pb} not found in DLE pressure data: {pressures}")
    pb_idx = pb_idx[0]
    bodb = bo_dle[pb_idx]    # Bo at bubble-point
    rsds = rs_dle[pb_idx]    # Rs at bubble-point
    sod = bo_dle / bodb
    bo_corrected = np.zeros_like(bo_dle)
    for i, p in enumerate(pressures):
        if p >= pb:
            bo_corrected[i] = vrel[i] * bofb
        else:
            bo_corrected[i] = bofb * sod[i]
    rs_corrected = np.zeros_like(rs_dle)
    for i, p in enumerate(pressures):
        if p >= pb:
            rs_corrected[i] = rsfb
        else:
            rs_corrected[i] = rsfb - (rsds - rs_dle[i]) * (bofb / bodb)
    return bo_corrected, rs_corrected
```

Purpose:

- Adjusts Bo to separator conditions.

Example:

At p = 5015 psia, Vrel = 0.9632, Bofb = 1.334 → Bo_corrected = 0.9632 * 1.334.

Correction Calculations – Rs Correction

Logic:

- Above bubble-point (p >= pb):

  Rs_corrected = Rsfb

  Rs remains constant above Pb.

- Below bubble-point (p < pb):

  Rs_corrected = Rsfb - (Rsds - Rsd) * (Bofb/Bodb)

  Rsds: Rs at bubble-point; Rsd: Rs at current pressure.

```
rs_corrected = np.zeros_like(rs_dle)
for i, p in enumerate(pressures):
    if p >= pb:
        rs_corrected[i] = rsfb
    else:
        rs_corrected[i] = rsfb - (rsds - rs_dle[i]) * (bofb / bodb)
return bo_corrected, rs_corrected
```

Purpose:

- Adjusts Rs to separator conditions.

Example:

At p = 1515 psia, Rsfb = 494, Rsds = 563, Rsd = 522.2 → Adjusted Rs

Main Function – Workflow

Steps:

1. Prompts user for CSV file paths.
2. Imports and validates CCE, DLE, and Separator tests data.
3. Validates bubble-point pressure.
4. Extracts optimum separator conditions (Bofb, Rsfb).
5. Performs DLE correction.
6. Creates separate Bo and Rs plots.
7. Visualizes and exports results into excel file, if requested.

Key Feature:

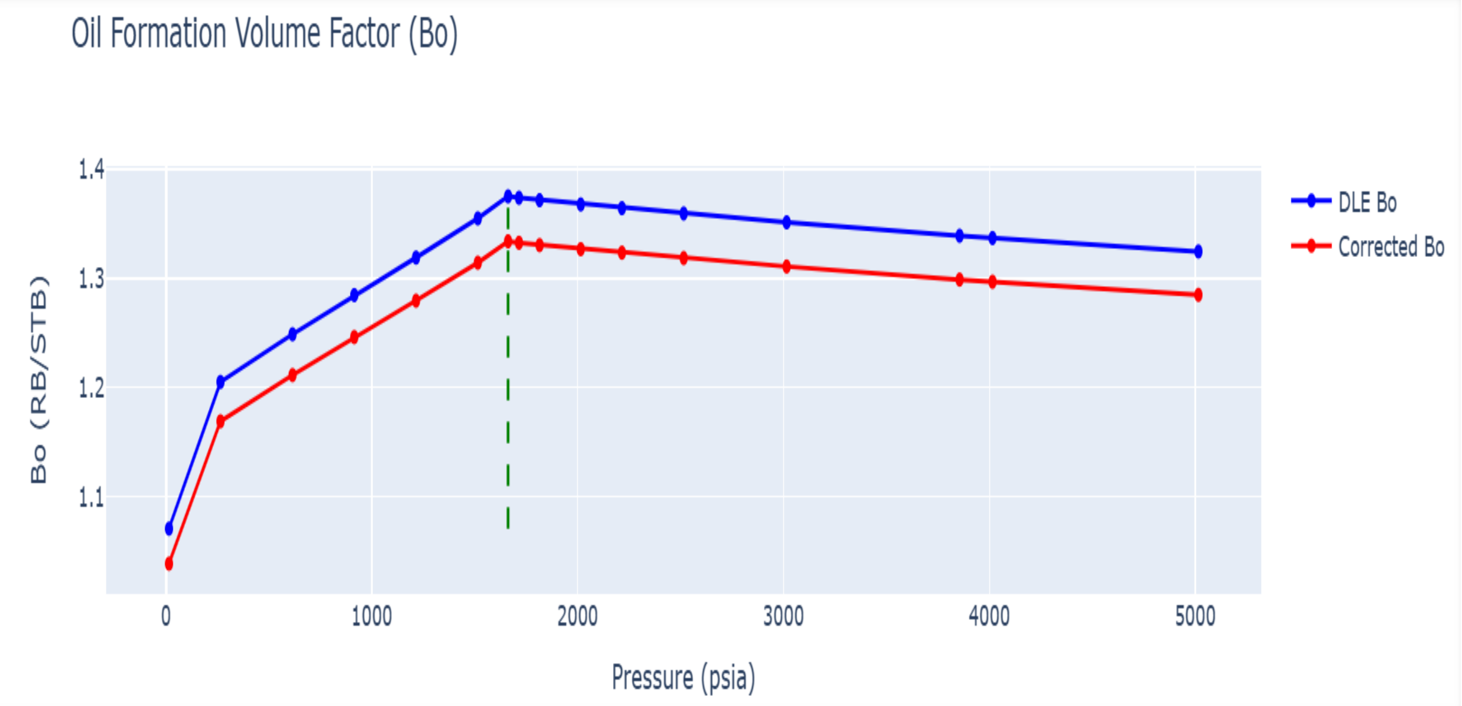
Robust error handling for missing or invalid data.

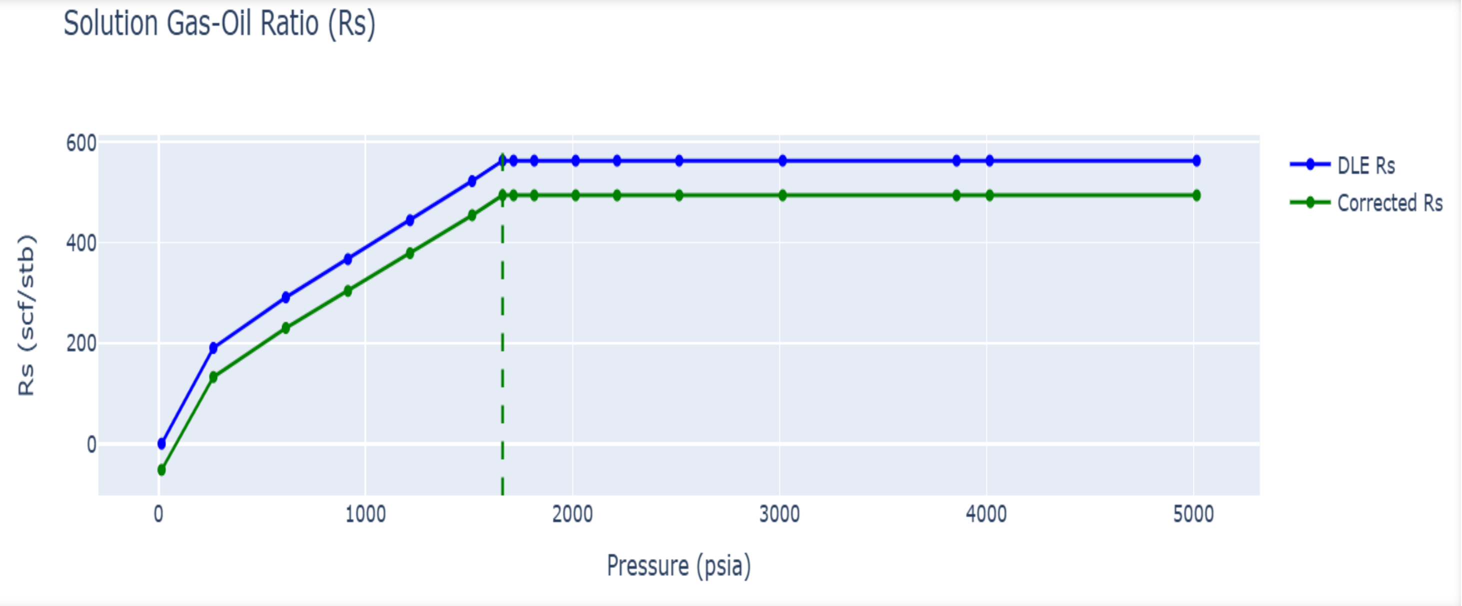
Main Function – Visualization with Plotly Express

- Plots:
  - Separate plots for Bo and Rs.
  - DLE vs. corrected values with a vertical line at pb.
- Purpose:
  - Quality control (QC) to verify correction accuracy.

Benefit:

- Visual confirmation of correction impact.





Efficiency and Practical Benefits of DLE Correction

Automation:

- Reduces manual correction time from hours to minutes.

Accuracy:

- Aligns DLE data with field conditions, improving simulation reliability.

Practical Impact:

- Better reserve estimation and production optimization.

Example (Well AB):

Corrected Bo at 5015 psia: Reduced from 1.3247 to 1.2849 RB/STB.

Ensures accurate material balance calculations.

Scalability:

- Handles large datasets efficiently with Pandas.

References

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Questions?