2016 APL Problem Solving Competition – Phase 2 Problem Descriptions

Overview

This year's Phase II problems are divided into three sets, representing three categories – Bioinformatics, Finance and General Computing. Each set has three problems; a problem can be broken down into multiple tasks.

Three grand prizes will be awarded, one in each of the categories.
To be considered for a grand prize, you must solve all of the problems in a category.

You may submit an entry that completes more than one category. However, you can only win once – for example, if your entries in all three categories are judged to be the best in each category, the judging committee will select the entry they deem the best and declare you the winner in that category while other competitors will be selected as the winners of the other categories.

Good Luck and Happy Problem Solving!

Note:
Some of the examples are displayed using the user command setting `]boxing on` to more clearly depict the structure of the displayed data.

```
      ('Dyalog' 'APL')(4 4⍴⍳16) 5
  Dyalog  APL    1  2  3  4  5
                 5  6  7  8
                 9 10 11 12
                13 14 15 16

      ]boxing on
Was OFF

      ('Dyalog' 'APL')(4 4⍴⍳16) 5
┌─────────────┬───────────┬─┐
│┌──────┬───┐ │ 1  2  3  4│5│
││Dyalog│APL│ │ 5  6  7  8│ │
│└──────┴───┘ │ 9 10 11 12│ │
│             │13 14 15 16│ │
└─────────────┴───────────┴─┘
```

Description of the Contest2016 Template Files

Two template files are available for download from the contest website. Which file you use depends on how you choose to implement your problem solutions.

If you use Dyalog APL, you should use the template workspace `Contest2016.DWS`

The Contest2016 workspace contains:

- Three namespaces, one for each of the problem categories. Each namespace will contain:
  - stubs for all of the functions described in the problem descriptions. The function stubs are implemented as traditional APL functions (tradfns) but you can change the implementation to dynamic functions (dfns) if you want to do so. Either form is acceptable.
  - any sample data elements mentioned in the problem descriptions.

  Any sub-functions that you develop as a part of your solution should be co-located in the category namespace.

  The namespaces are:

  - `#.bio` – for the bioinformatics problem set
  - `#.fin` – for the finance problem set
  - `#.gen` – for the general computing problem set

- **`#.SubmitMe`** – a function used to package your solution for submission.

Make sure you save your work using the `)SAVE` system command!

Once you have developed and are ready to submit your solutions, run the **`#.SubmitMe`** function, enter the requested information and click the **Save** button. **`#.SubmitMe`** will create a file called **Contest2016.dyalog** which will contain any code or data you placed in the **`#.bio`**, **`#.fin`**, and **`#.gen`** namespaces. You will then need to upload the **Contest2016.dyalog** file using the contest website.

If you use some other APL system, you can use the template script file `Contest2016.dyalog`

This file contains the correct structure for submission. You can populate it with your code, but do not change the namespace structure. Once you have developed your solution, edit the variable definitions as indicated at the top of the file and upload the file using the contest website. If you use some other APL system to develop your application, **it will still need to execute under Dyalog APL**; it is recommended that your solution use APL features that are common between your APL system and Dyalog.

Set 2: Finance Problems

Finance Problem 1 – (1 task)

Task 1 – Calculating Forward Rates from the Yield Curve

According to Investopedia - A yield curve is a line that plots the interest rates, at a set point in time, of bonds having equal credit quality, but differing maturity dates. The most frequently reported yield curve compares the three-month, two-year, five-year and 30-year U.S. Treasury debt. This yield curve is used as a benchmark for other debt in the market, such as mortgage rates or bank lending rates. The curve is also used to predict changes in economic output and growth.

The spot rate is the return on a bond of a specified maturity (contract length) purchased immediately.
The forward rate is the predicted yield of a bond purchased at a specified time in the future.

Forward rates can be estimated from spot rates on the yield curve in the following manner[1]:

$$F_{1,2} = \frac{R_2 T_2 - R_1 T_1}{T_2 - T_1}$$

where R_1 and R_2 are consecutive spot rates on the yield curve and T_1 and T_2 are their corresponding maturities.

For example, a 1-year bond has a spot rate of 2.96% and a 2-year bond has a spot rate of 3.29%, then the market's expectation for the spot rate for a 1-year bond purchased 1 year from now, the forward rate, can be calculated as:

$$F_{1,2} = \frac{(3.29 \times 2) - 2.96}{2 - 1} = 3.62$$

Write an APL function named `forward` which

- takes a numeric vector left argument representing a list of maturities expressed in years; fractional years are allowed (e.g. .25 would correspond to a 3-month maturity)
- takes a numeric vector right argument representing a list of spot rates
- returns a numeric vector of the computed forward rates

Example:

We first create a vector of maturities expressed in years:

```
 maturities←.25 .5 1 2 3 5 7 10 20
```

Next we create a vector of Treasury spot rates (the yield curve) obtained from the U.S. Treasury web site corresponding to those maturities:

```
 rates←2.51 2.79 2.96 3.29 3.43 3.71 3.92 4.14 4.64
```

```
      maturities forward rates
2.51 3.07 3.13 3.62 3.71 4.13 4.445 4.6533 5.14
```

Note: the first forward rate is the same as the first spot rate; the second forward rate uses the first and second spot rates and the first and second maturities; the third forward rate uses the second and third values, etc.

[1] (Source: Hull, John C. *Options, Futures and Other Derivatives, 5th Edition.* P. 93 Prentice-Hall, 2003. page 99)

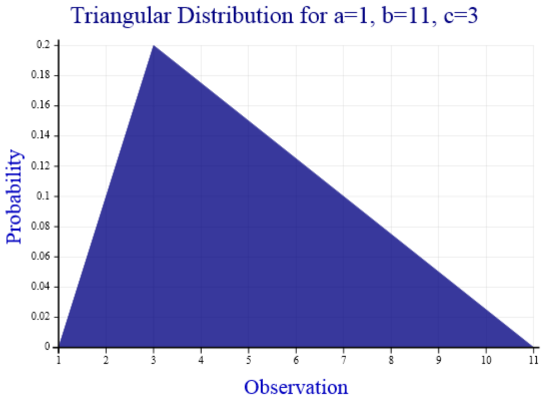
Finance Problem 2 – (2 tasks)

Triangular Distribution

Wikipedia defines triangular distribution as follows:

In probability theory and statistics, the triangular distribution is a continuous probability distribution with lower limit **a**, upper limit **b** and mode **c**, where **a < b** and **a ≤ c ≤ b**.

A probability density function (PDF), or density of a continuous random variable, is a function that describes the relative likelihood for this random variable to take on a given value.



Produced using Dyalog APL Chart Wizard

***Task 1** – What's the density?*

Write an APL function named **`pdf`** which implements the probability density function a triangular distribution and which:

- takes a single numeric right argument
- takes a 3-element numeric vector left argument describing the triangular distribution (representing **a**, **b**, and **c** respectively)
- returns the value of the probability density function for the triangular distribution described by the right argument . The value should be between 0 and 1.

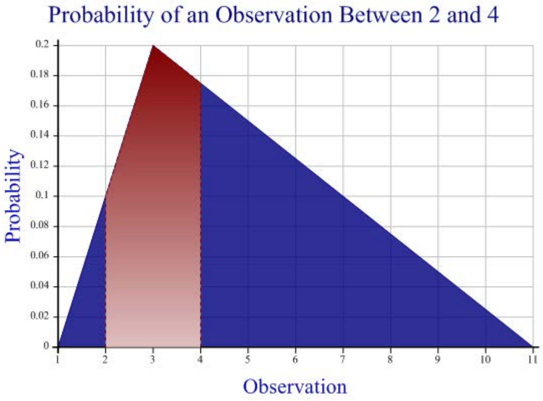
Example:

```
      1 11 3 pdf 3  ⍝ what's the probability density at 3?
0.2

      'X' 'P(X)'⍪(⍳11),⍪1 11 3∘pdf¨⍳11    ⍝ probability density table for integer
values
 X  P(X)
 1  0
 2  0.1
 3  0.2
 4  0.175
 5  0.15
 6  0.125
 7  0.1
 8  0.075
 9  0.05
10  0.025
11  0
```

Task 2 – What's the probability?

Suppose we want to find the probability of an observation within a range. For example, what's the probability of an observation between 2 and 4 occurring?



Produced using Dyalog APL Chart Wizard

Write an APL function named **pdf2** which:

- takes either a single numeric right argument or a 2-element numeric vector representing an observation or a range of observations.
- takes a 3-element numeric vector left argument representing **a**, **b**, and **c** respectively
- returns the probability (expressed as a number between 0 and 1) that a value in the right argument will occur in the distribution described by the left argument

Example:

```
      1 11 3 pdf2 3    ⍝ what's the probability density at 3?
0.2

      1 11 3 pdf2 2 4  ⍝ what's the probability a value between 2 and 4 will occur?
0.3375
```

Finance Problem 3 – (1 task)

Take a Trip to Monte Carlo

Monte Carlo methods in finance are often used to evaluate investments in projects at a business unit or corporate level, or to evaluate financial derivatives. They can be used to model project schedules, where simulations aggregate estimates for worst-case, best-case, and most likely durations for each task to determine outcomes for the overall project. Monte Carlo methods are also used in option pricing and default risk analysis.[2]

This problem uses Monte Carlo methods to evaluate the proposed release of a new product.

The profitability of a product can be oversimplified to:

$$\mathbf{profit} = \left(\mathbf{unitsSold} \times (\mathbf{unitPrice} - \mathbf{unitCost})\right) - \mathbf{fixedCosts}$$

In our model:

- The number of units sold and the price per unit can vary based on the economic climate.
- Unit cost can vary based on suppliers, labor costs, etc.
- Fixed costs are known and don't have any variability.

Our sales forecasters have estimated the following scenarios over the expected lifetime of the product:

Economic Climate	Likelihood	unitsSold	unitPrice
Recession	10%	50,000	$13.00
Slow	30%	75,000	$10.00
Moderate	40%	100,000	$8.50
Hot	20%	125,000	$8.00

Our production planning department estimates that the **unitCost** will vary from $5.00 to $8.00 with a most likely value of $7.00. This sounds like an excellent opportunity to use triangular distribution.
fixedCosts are known to be $125,000.

[2] Wikipedia

Task 1 – Go or No Go?

Your job is to build a model to determine the likelihood that going forward with the production of this product will be profitable. You should run the simulation for a minimum of 10,000 trials.

Your task is to write an APL function named **`profit`** which:

- returns a 2-column numeric matrix of:
  - `[;1]` profit (or loss) in $10,000 increments
  - `[;2]` the probability expressed as a percentage to 2 decimal places

Example (N.B. the numbers below are made up to show the formatting and are not indicative of actual values):

```
      profit
¯10000  6.12
     0 17.34
 10000 46.91
 20000 20.11
 30000  9.52
```

These results would indicate a 6.12% chance of losing $0-$10,000, a 17.34% chance of making $0-$10,000, a 46.91% chance of making $10,000-$20,000, etc.

Note:
You can structure the arguments to the model in any way you choose – for example, global variables, variables defined inline within `profit`, etc.