Dyalog 2010 Programming Contest

You've decided that it is time to have a home of your own, but you can't decide whether to buy or rent. Renting is easier to understand, but over time you suspect that owning your home might be a better deal. You are lucky enough to have parents who have offered to lend you SOME of the money at a favourable rate, and might be more forgiving of late payments – but you'd still like to explore the problem space in a little more depth. You decide to build a model in APL.

Prizes in this year's contest will be awarded for the best overall solutions to the six programming tasks described in the following. In addition, prizes will be awarded for the three best *presentations* of data arising from working on the problems – without regard to how well the main programming tasks were solved.

The financial model is based upon 12 input parameters:

Parameter Name	Description	Example Value
PRICE	Home purchase price	150,000
COSTS	One-time closing costs	5,000
TERM	Term of loan (months)	360
BANKAMT	Amount borrowed from bank	75,000
BANKRATE	.. at annual mortgage rate (%)	10
DADAMT	Amount borrowed from parents	30,000
DADRATE	.. at annual mortgage rate (%)	5
INFL	Annual inflation rate (%)	1.5
TAXRATE	Marginal income tax rate (%)	25
PROPRATE	Annual property tax rate (%)	1.75
SAVRATE	Savings/investment rate (%)	3
INITRENT	Initial monthly apartment rent	600

The parameters used in the example should not be taken as predictions of economic conditions in any country - they were simply selected to give an interesting looking curve which ended with buying becoming being more advantageous at the end of the loan term. The output of the model is 15 monthly "time series". In the above example, there would be 360 months of output, the first three months of which are:

	Series Name	Variable Name	1st Month	2nd Month	3rd Month
1.	After Month	I	1	2	3
2.	Bank Interest	BANKINT	625.00	624.72	624.44
3.	Bank Repayment	BANKPRN	33.18	33.46	33.73
4.	Bank Loan Balance	BANKBAL	74,966.82	74,933.37	74,899.63
5.	Parent Interest	DADINT	125.00	124.85	124.70
6.	Parent Repayment	DADPRN	36.05	36.20	36.35
7.	Parent Loan Balance	DADBAL	29,963.95	29,927.76	29,891.41
8.	Mortgage Tax Savings	TAXSAVE	156.25	156.18	156.11
9.	Property Taxes	PROPTAX	0.00	0.00	0.00
10.	Value of Home	HOMEVAL	150,186.22	150,372.68	150,559.36
11.	Savings While Owning	SAVEOWN	-662.98	-1,327.26	-1,992.87
12.	Home Cashout Value	HOMECASH	44,592.47	44,184.29	43,775.46
13.	Rent Payment	MORENT	600.00	600.00	600.00
14.	Savings While Renting	SAVRENT	49,493.75	48,986.55	48,478.40
15.	Advantage of Buying	ADVAN	-4,901.28	-4,802.26	-4,702.94

Formulae

The mathematical formulae used to compute these values are described in this section.

The bank loan is amortized though equal payments over the entire term, using the following formulae:

BANKMR = Bank monthly mortgage rate
= BANKRATE/12

BANKPMT = Bank monthly payment
= BANKAMT x BANKMR/(1-(1+BANKMR)^-TERM)

BANKBAL[0] = Initial bank loan balance
= BANKAMT

BANKINT[I] = Bank mortgage interest in month I
= BANKBAL[I-1] x MORATE

BANKPRN[I] = Bank principal repaid in month I
= BANKPMT - BANKINT[I]

BANKBAL[I] = Bank loan balance after month I
= BANKBAL[I-1] - BANKPRN[I]

Formulae for the following five items are parallel to the above formulas:

DADMR = Parent monthly mortgage rate
DADPMT = Parent monthly payment
DADBAL = Parent loan balance
DADINT = Parent mortgage interest
DADPRN = Parent principal repaid

The remaining values are computed as follows:

HOMEVAL[0] = Initial value of home

HOMEVAL[I] = Value of home after month I
= HOMEVAL[I-1] x ((1+INFL)^(1/12))
(Home value appreciates at inflation rate)

PROPTAX[I] = Property taxes paid during month I
= HOMEVAL[I-6] x PROPRATE/2
(for months 6, 18, 30, 42,...)
= HOMEVAL[I-12] x PROPRATE/2
(for months 12, 24, 36, 48,...)
(Property taxes are computed annually and
paid semiannually)

TAXSAVE[I] = Mortgage tax savings during month I
= BANKINT[I] x TAXRATE
(Interest portion of bank mortgage payments are
tax-deductible; payments to parents are not)

SAVEOWN[0] = Initial savings while owning
= 0

SAVEOWN[I] = Savings while owning, through month I
= (SAVEOWN[I-1] x (SAVRATE/12) x (1-TAXRATE))+
TAXSAVE[I] - (PROPTAX[I] + BANKPMT + DADPMT)

HOMECASH[I] = Home cashout value, after month I
= HOMEVAL[I] + SAVEOWN[I] -
(BANKBAL[I] + DADBAL[I])

MORENT[0] = Initial monthly rent payment
= INITRENT

MORENT[I] = Monthly rent payment
= MORENT[I-1] x (1+INFL)
(for months 13, 25, 37, 49,...)
= MORENT[I-1]
(for all other months)
(Rent increases once a year, at inflation rate)

SAVERENT[0] = Initial savings while renting
= (PRICE + COSTS) - (BANKAMT + DADAMT)
(This amount is saved by not buying)

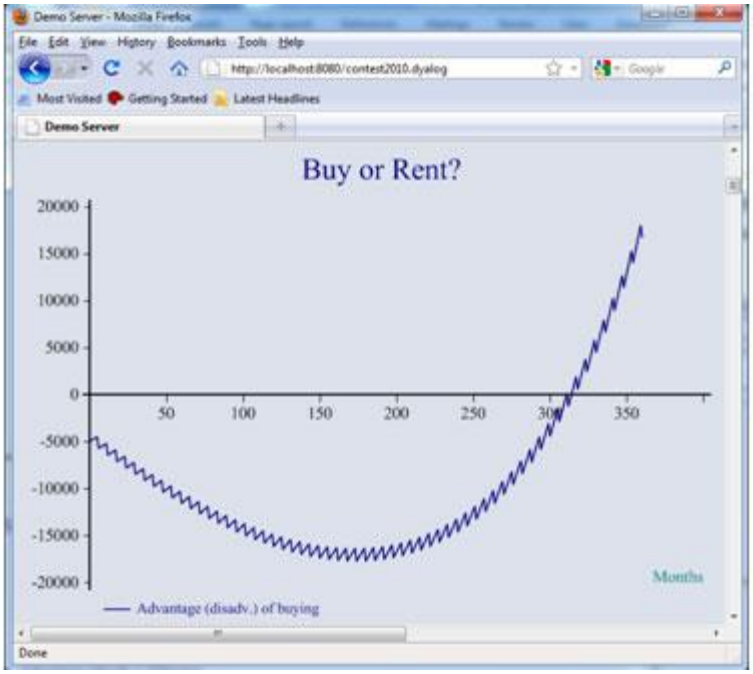
SAVERENT[I] = Savings while renting, through month I
= (SAVERENT[I-1] x (SAVRATE/12) x (1-TAXRATE))
- MORENT

ADVAN[I] = Advantage (disadvantage) of buying
= HOMECASH[I] - SAVERENT[I]

The BuyRentCase XML format

A complete "Buy or Rent Case" can be represented as an XML file containing both the input paramaters and the resulting timeseries. A complete **BuyRentCase** file contains both a BuyRentParams element containing a set of input parameters and an element called BuyRentResults with the results (example of a complete xml file listing). One of the first tasks will be to read input parameters from such a file, which might look like this (if it only contains input parameters and no results):

```
<BuyRentCase>
  <BuyRentParams HomePrice="150000" ClosingCosts="5000" LoanTerm="360"
      BankAmount="75000" BankRate="10" DadAmount="30000" DadRate="5"
      Inflation="1.5" MarginalTax="25" PropertyTax="1.75" SavingsRate="3"
      InitialRent="600" />
</BuyRentCase>
```



Graph showing the Advantage of Buying over 360 months.

Your Task

You need to solve as many of the following tasks - 1 to 6 - as possible. To win one of the three main prizes you must solve all of the tasks. It is only necessary to solve two tasks - freely selected from those described on this page and those posed in the Rosetta Challenge, in order to participate in the draw for consolation prizes.

1. Input Processing

Write an APL function called **GetBuyRentParams** which processes XML representing a BuyRentCase and extracts the input parameters. The function should take a character vector containing XML as the right argument, and return a 12-element numeric vector containing the twelve input parameters to the model, in the same order as the table in the introduction.

Hint: The task does not require you to read text files containing XML, but if you would like to store your input data in files, we suggest that you take a look at the workspace FILES (included with Dyalog APL) for tools to read and write files.

2. Base Model Calculation

Write an APL function called **BuyOrRent**, which takes a twelve-element numeric vector of input parameters (which might have been produced by **GetBuyRentParams**) as a right argument, and returns a nested vector with two elements. The first element of the result should be a two-element numeric vector containing the monthly payment amounts to the Bank and Parents, respectively. The second element should be a matrix with one row per month, and 15 columns – one for each of the output timeseries (in the example, the shape of this part of the result should be 360 by 15).

3. Aggregation Function

Write a function named **AggregateSeries**, which *aggregates* the timeseries contained in each column of an input matrix. The right argument should be a matrix (like the second element of the result of **BuyOrRent**). The left argument should be a 2-element vector, where the first element is the number of input periods to be aggregated into each row of output, and the second element is a character vector with one element for each input column, specifying the aggregation function to be used, using one of the following characters: S (sum), A (average), M (maximum), F (first), L (last).

If “mat” is a 4 by 4 matrix containing the integers 1 through 16:

```
      mat
 1   2   3   4
 5   6   7   8
 9  10  11  12
13  14  15  16
```

then the expression:

```
      2 'SAMF' AggregateSeries mat
```

should produce the result:

```
 6   4   7   4
22  12  15  12
```

4. Goal Seeking

Write an APL function **SeekBuyRentParam**, which takes as its right argument a vector of 12 BuyRentParams, where one of the parameters has been replaced by the character '**?**'. As a left argument, the function will receive a desired value for the "Advantage of Buying" at the end of the loan term. The function should find and return a value for the missing parameter which produces the desired advantage, to within one unit of our currency. If the function is not able to find a suitable value, it should signal a DOMAIN ERROR. For example, if we look at the example problem and would like to know what the initial rent needs to be in order for buying and renting to be exactly equal in terms of the final outcome (Advantage of Buying = 0), we should be able to use this function as follows:

```
      0 SeekBuyRentParam 150000 5000 360 75000 10 30000 5 1.5 25 1.75 3 '?'
573.2682766
```

In other words, if the initial rent is lowered to 573, then buying and renting are equally advantageous.

5. Variable Interest

You have agreed with your parents that the interest rate on that loan will remain fixed – and we won’t try to compute a net present value of the obligations (dog walking, grandchild

sitting, lawn mowing, snow clearing, and so forth, depending on your climate) that are attached to this loan.

However, the bank offers you the option of a variable interest loan, based on the official rate which is fixed by the central bank, each quarter. At the beginning of each year, your bank will adjust the interest on variable-interest loans to the rate which the central bank has set for the quarter which is just starting. It will re-compute your monthly payments using the standard amortization formula, using the new interest rate and the number of months remaining.

The steering committee in the central bank consists of a bunch of old role players, who have agreed to pursue a fiscal policy based on rolling a single six-sided die. They adjust the interest rate using the number that they get by subtracting 3.5 from the number of pips and dividing by 10, with the limitation that the interest rate cannot go below zero.

Write a function **VariableRisk**, which accepts a set of BuyRentParams on the right (representing the fixed-interest base scenario), and on the left a two-element vector containing the initial interest rate for the variable-interest loan and the number of simulations to run. By running simulations, the function should return a vector of five probabilities (as numbers between 0 and 1), showing the probability that the variable-interest loan will be 1) more than 50,000 more favourable, 2) more than 25,000 but no more than 50,000 more favourable, 3) within 25,000 of the fixed loan, 4) more than 25,000 but no more than 50,000 less favourable, 5) more than 50,000 less favourable than the fixed loan. For example (the following result is not necessarily the "right" answer):

```
      9 10000 VariableRisk 150000 5000 360 75000 10 30000 5 1.5 25 1.75 3
600
0.1219 0.5192 0.3582 0.0007 0
```

6. Optimised VariableRisk Function

Write a version of the **VariableRisk** function, called **VariableRiskFast**, which will be judged on how fast it runs on the following problem:

```
      8.5 10000 VariableRiskFast 150000 5000 360 75000 10 30000 5 1.5 25 1.75 3 600
```

The ***only*** criteria used to judge your solution to this task will be the execution speed of the function on the above problem. No subjective criteria will be applied.

Restrictions

The solutions may not make use of any "external" tools or utility libraries not provided as part of a standard Dyalog APL installation.

Submitting Solutions

Solutions should either be submitted as a single UTF-8 file representing a Dyalog namespace containing your solutions - or a single Dyalog workspace containing that namespace. You

may use any APL system to generate the code, so long as your submittion is loadable using Dyalog version 12.1.

Judging Criteria

With the exception of the final task, which will be measured exactly, the correct submissions will be evaluated by a panel of judges with considerable experience in the development of APL-based solutions. The criteria used to evaluate your submission include, but are not limited to:

- Did you solve the problem and get correct results?
- Clarity and structure of your solution. How well documented and organized is your solution? Can you pick up the code produced 6 months from now and still understand what it does?
- Use of APL. Does your solution use array-oriented processing where applicable? Solutions that look like C# translated into APL will receive less credit.
- Efficiency of your solution. How fast is your solution? With the exception of the final problem, you should not sacrifice clarity for speed.

The judges' determinations are final and cannot be contested under any circumstances

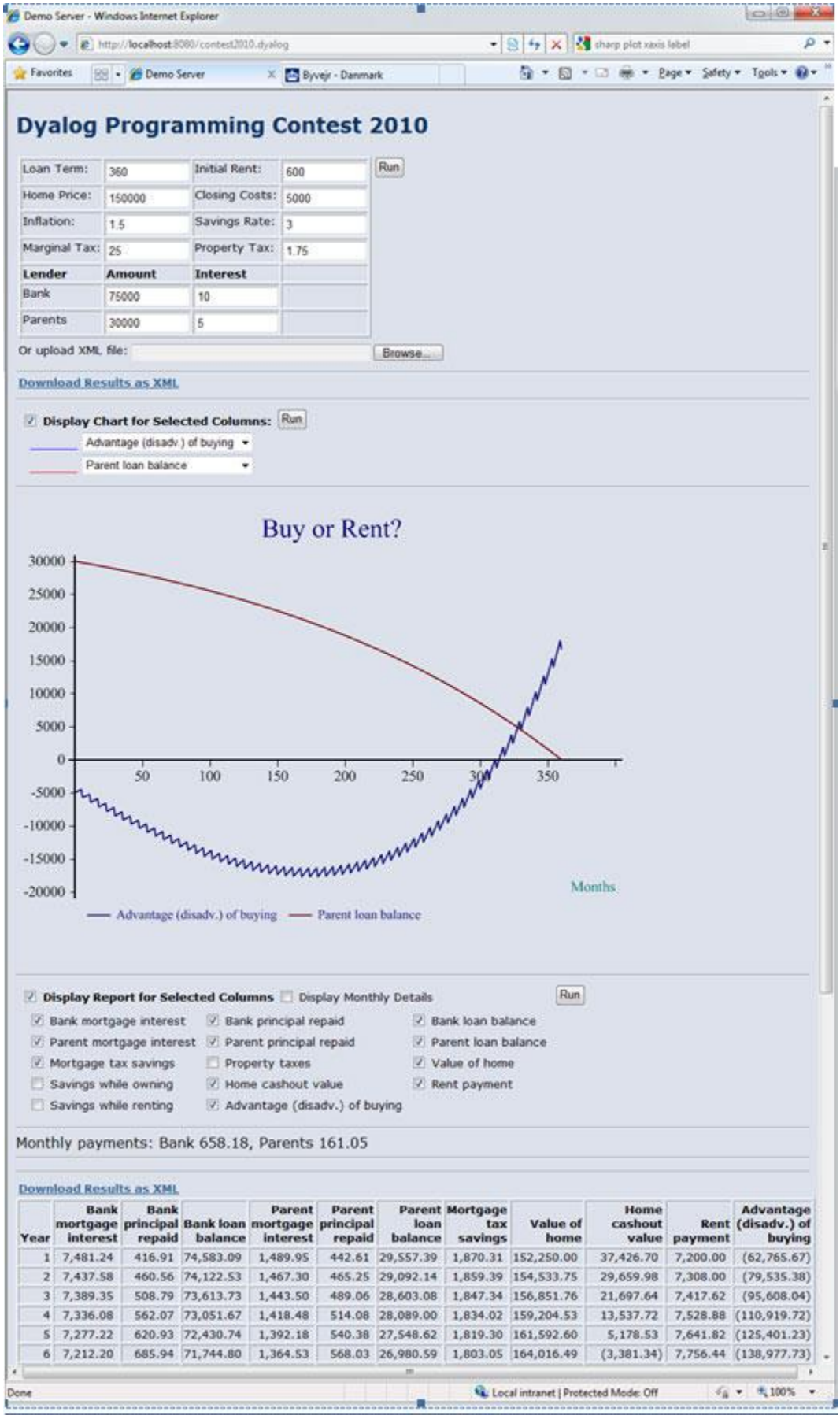
Presentation Prizes

In order to help visualize the results of the functions that you produce as solutions to the Programming Contest, we have prepared a Web Page which will call many of the functions described above. This solution has been built using the *MildServer*, which is a simple web server written entirely in Dyalog APL (in other words, you do not need to be running Apache, IIS or any other web server in order to use it). You can download and install the MildServer from the APL Wiki, see http://aplwiki.com/MildServer.

Once the MildServer is installed, all you need to do to integrate your solutions with it is to copy the file Contest2010sample.dyalog (which you can download from the page containing sample submissions) to the "Demo" folder of your MildServer installation, and then replace the empty shell functions that it contains with any solutions that you have coded, in order to get the web page to display computed values. The functions that need to be replaced are those which follow the comment which reads:

--- Overwrite the following functions with your own solutions ---

If you have correctly installed the MildServer and the sample page, and direct your web browser to the address http://localhost:8080/Contest2010, you should see a page similar to the following (you will need to select one or two data items in order to get a graph):


Demo Server - Windows Internet Explorer
http://localhost:8080/contest2010.dyalog
sharp plot xaxis label
Favorites
Demo Server
Byvejr - Danmark
Page
Safety
Tools
Dyalog Programming Contest 2010
Loan Term: 360
Initial Rent: 600
Run
Home Price: 150000
Closing Costs: 5000
Inflation: 1.5
Savings Rate: 3
Marginal Tax: 25
Property Tax: 1.75
Lender
Amount
Interest
Bank
75000
10
Parents
30000
5
Or upload XML file:
Browse...
Download Results as XML
Display Chart for Selected Columns:
Run
Advantage (disadv) of buying
Parent loan balance
Buy or Rent?
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
50
100
150
200
250
300
350
Months
Advantage (disadv.) of buying
Parent loan balance
Display Report for Selected Columns
Display Monthly Details
Run
Bank mortgage interest
Bank principal repaid
Bank loan balance
Parent mortgage interest
Parent principal repaid
Parent loan balance
Mortgage tax savings
Property taxes
Value of home
Savings while owning
Home cashout value
Rent payment
Savings while renting
Advantage (disadv.) of buying
Monthly payments: Bank 658.18, Parents 161.05
Download Results as XML
Year
Bank mortgage interest
Bank principal repaid
Bank loan balance
Parent mortgage interest
Parent principal repaid
Parent loan balance
Mortgage tax savings
Value of home
Home cashout value
Rent payment
Advantage (disadv.) of buying
1 7,481.24 416.91 74,583.09 1,489.95 442.61 29,557.39 1,870.31 152,250.00 37,426.70 7,200.00 (62,765.67)
2 7,437.58 460.56 74,122.53 1,467.30 465.25 29,092.14 1,859.39 154,533.75 29,659.98 7,308.00 (79,535.38)
3 7,389.35 508.79 73,613.73 1,443.50 489.06 28,603.08 1,847.34 156,851.76 21,697.64 7,417.62 (95,608.04)
4 7,336.08 562.07 73,051.67 1,418.48 514.08 28,089.00 1,834.02 159,204.53 13,537.72 7,528.88 (110,919.72)
5 7,277.22 620.93 72,430.74 1,392.18 540.38 27,548.62 1,819.30 161,592.60 5,178.53 7,641.82 (125,401.23)
6 7,212.20 685.94 71,744.80 1,364.53 568.03 26,980.59 1,803.05 164,016.49 (3,381.34) 7,756.44 (138,977.73)
Done
Local intranet | Protected Mode: Off
100%

To enter the competition for the Best Presentation, you need to submit code which presents any of the data that you encountered while solving (or merely investigating) the other tasks. The judges will select the three best presentations based on how well they feel each presentation illuminates some aspect of the problem space described in the tasks – WITHOUT regard to what the code which produces it looks like, how efficient it is, or (within reason) how correct the presented data is.

The preferred form of solution is a MildServer page (which could be derived from the sample). At Dyalog's discretion, selected MildServer solutions will be displayed on Dyalog's web server after the closing date for submissions (credit will be given to the authors).

Alternatively, you may add a niladic APL function called **Presentation** to your submitted namespace. This function should produce some kind of visual presentation when executed. The MildServer example uses a charting tool called SharpPlot, which is included with Dyalog APL, but requires the Microsoft.Net framework. You may use any presentation tool that you wish, but you may not use code written in any language other than Dyalog APL to generate the presentation. For example, if you use Microsoft Excel, you must perform *ALL* the automation required to produce the presentation from APL; you may not use scripts internal to Excel. If you use a tool which is not readily available to the judges, you are less likely to win, but if you include screen shots, we will attempt to judge your solution based on these and a reading of your code.

Rosetta Challenge

The Rosetta Code page at http://www.rosettacode.org contains solutions to 400 programming tasks, implemented in a wide variety of programming languages. Currently, only a few of the tasks have APL solutions. We have selected five tasks which look as if they might be fun to work on:

- Animate a pendulum
- Knapsack problem
- Happy numbers
- Hofstadter-Conway $10,000 sequence
- Monty Hall problem

For each task, there is a prize for the best solution.

The five Rosetta Challenge tasks are completely independent of the main Dyalog Programming Contest: you do not need to submit solutions to the main contest tasks in order to participate in the Rosetta Challenge.

Your Task

For each of the following Rosetta Code tasks, you must write an APL function which works as described in the following task descriptions. It is only necessary to solve two tasks - freely

selected from those described on this page and those posed in Dyalog 2010 Programming Contest in order to participate in the draw for consolation prizes.

1. Animate a Pendulum

The task is introduced on the page http://rosettacode.org/wiki/Animate_a_pendulum. You must write an APL function called **AnimatePendulum**, which takes as its right argument a vector of six numbers:

- [1] Time interval in seconds between successive "frames"
- [2] Starting angle in degrees (rotating clockwise from vertical)
- [3] Length of pendulum in metres
- [4] Gravitational constant in m/s^2
- [5] Initial velocity in m/s
- [6] Number of seconds to run the simulation (0=no limit)

The function should produce an animated graphical representation of a swinging pendulum, in some form of window, using **ANY** technique available from Dyalog APL (anything from "ASCII art" via native Dyalog GUI to XAML/WPF is acceptable).

In addition, the function should return a vector containing the angle of rotation for the first 50 "frames", in order to allow automated verification.

2. Knapsack Problem

Write an APL function called **Knapsack**, which takes a left argument which is a maximum weight, and a right argument which is a matrix with three columns containing item names, weights (in the same units as the left argument) and values (in other words, data corresponding to the table at the top of the page http://rosettacode.org/wiki/Knapsack_problem/0-1). The function should return a vector of item names (selected from the first column), for those items which should be selected to go in the knapsack.

3. Happy Numbers

Write an APL function called **HappyNumbers**, which returns a vector containing the first 8 happy numbers. See http://rosettacode.org/wiki/Happy_numbers for more details.

4. Hofstadter-Conway $10,000 Sequence

Write an APL function named **HC10k**, which returns a 20-element vector containing maxima of a(n)/n between successive powers of two up to 2^20, as described on the page http://rosettacode.org/wiki/Hofstadter-Conway_$10,000_sequence.

5. Monty Hall Problem

Write an APL function **MontyHallSim**, which takes as its right argument the number of simulations to run, and returns a 2-element vector containing the probability of winning if you "stay", and the probability of winning if you "switch". You can find a description of the Monty Hall problem at http://rosettacode.org/wiki/Monty_Hall_problem.