AN ADAPTATION OF EVOLUTIONARY STRATEGIES FOR FORECASTING THE EXCHANGE RATE

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ABSTRACT: In this paper, we propose an adaptation of evolutionary strategies (ES) for forecasting the exchange rate. The proposed method employed the evolution of the functional form as well as its coefficients. Using mutation, the functional form is evolved from an initial population. Evolution strategies is used to search for coefficients of functions. We used the data of bath/us-dollar exchange rate from Bank of Thailand during the year 1998. The result is validated using 10-fold cross validation method. The error is less than 5% on training data and testing data. The error on best predictor on testing data is 1.19%. The main contribution of the proposed method is the evolution of the functional form as a separate phase and then using ES to evolve the real value coefficients. The proposed method has been shown to work well in the forecasting task. It is expected to be suitable for variety of tasks that the functional form are not known apriori.

KEYWORDS: evolutionary strategies, forecasting, time series, functional form

1. INTRODUCTION

Evolutionary strategies (ES) is an optimization method proposed by Ingo Rechenberg (Rechenberg 1973) for optimise real value parameters. In ES, the representation used is a fixed-length real-valued vector. A vector of real values represents an individual. The standard deviation is used to control search strategy in ES. The main operator in ES is Gaussian mutation, in which a random value from a Gaussian distribution is added to each element of an individual's vector to create a new offspring. In this paper, we use (1+1)-ES for selection process. (1+1)-ES used mutation scheme only and worked on one population which produce one offspring. The better between parent and offspring is selected to the next generation. An introduction to ES can be found in (Rechenberg 1973, Back 1991 and Beyer 2002).

In forecasting task, the functional form is required apriori, ES is used to search coefficients of function. For examples, ES is used to find parameters of models for spectral analysis problems (Ramirez and Fuentes 2002), ES is used to find set of weights of a linear function in predicting the future inflation rate based on the inflation rate at the previous quarter (Kendall, Binner and Gazely 2001).

This paper proposed an adaptation of (1+1)-ES with evolution of functional form. It is not required to decide the functional form apriori in order to solve time series problems. The forecasting is illustrated using the exchange rate data. A function is composed of primitive functions, such as sin, cos, tan, exp and arithmetic operators: +, -, *, /. The function is randomly generated using the available symbol set. The (1+1)-ES method is used to evolve the coefficients. The objective function is to minimise the root mean square error of fitting between the evolved function and the training data set. The process starts with a randomly generated function. The mutation operator that works on the functional form changes at a random position, either the function or the operator at that position. After the functional form is changed, ES is used to search for the coefficients that minimise the RMS. The experiment is carried out to find a function that can predict the exchange rate data.

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2. ADAPTIVE EVOLUTIONARY STRATEGIES

The technique that we used is the mutation of functional form via the evolution process. In the beginning, the function is randomly generated. The function is constructed from primitive functions and arithmetic operators. Primitive function set in this paper are {x^a, $sin^b(ax)$, $cos^b(ax)$, $tan^b(ax)$, $e^{??\frac{?x?a?}{b}??^{2}}$}. The element x is a time series and value of a, b are any number, and arithmetic operator are {+, -, *, /}. Representation of a function and arithmetic operators are integer values. See **Table 1**.

Table 1. functions and operators

Functions and operators	+	-	*	/	*sin*	*Cos*	*tan*	*x*	*exp*
Encoded	0	1	2	3	4	5	6	7	8

A uniform random number generator is used to generate a function. The number that represents functions is chosen from a set of primitive functions separated by an operator. Initialization of coefficients a and b, with random real values except for exponents which are integers. Encoding of a function is shown in **Figure 1**. *Sd* is the standard deviation value used in controlling the search strategy.

c_0	c_1	c_2	c_3	…	c_n	sd

f_1	op_1	f_2	op_2	f_3	…	op_{n-1}	f_n	a_1	a_2	a_3	…	a_n	b_1	b_2	b_3	…	b_n

Figure 1. Encoding of an individual

The following example illustrates how a function is generated. Starting from the first symbol, suppose 4 is selected, the first term of a function is $sin^b(ax)$. Next, an operator is chosen, suppose it is 0, an operator is '+'. As the operator require two operands, another function is generated, suppose it is $cos^b(ax)$. The final objective function is $f(x) = sin^b(ax) + cos^b(ax)$.

When an objective function is selected, its coefficients are initially random. The number of coefficients depends on the number of terms in the function. The objective function is $f(x) = c_0 + c_1 sin^{b1}(a_1 x) + c_2 cos^{b2}(a_2 x)$. The encoding of this function is shown in **Figure 2**.

c_0	c_1	c_2	sd

4	0	5	a_1	a_2	b_1	b_2

Figure 2. Example

After an objective function is initialized, the evolution process begins. The fitness function is used to evaluate an individual. In this work, Root Mean Square error (RMS) is used for evaluation in order to minimise an error of fitting between the evolved function and the training data set (eq.1).

$$RMS = \sqrt{\frac{\sum_{t=1}^{n}\left(y_t - f(t)\right)^2}{n}} \quad (1)$$

In controlling the search strategy, an adjustment of standard deviation is considered from the ratio of a better individual during the evolution process, refer to 1/5 success rule (Rechenberg 1973) (eq.2) where p is probability that an offspring is better than its parent.

$$sd = \begin{cases} sd \div 0.817 & if(p > 1/5) \\ sd \times 0.817 & if(p < 1/5) \\ sd & if(p = 1/5) \end{cases} \quad (2)$$

The mutation of a real value coefficient is accomplished by sampling a value from normal distribution $Z_i \sim N_i(0, sd^2)$ and add that to the coefficient. The mutation of functional form changes a function or an operator to another function or operator at a random position. The pseudo code of adaptive evolutionary strategies is shown below.

```
t = 0
initialize functional form ( f )
initialize coefficient ( c )
initialize standard deviation ( sd )
I = ( f, c , sd )
e = evaluate (I)
while termination criterion not fulfilled do
    I' = mutate ( I)
    e' = evaluate (I' )
    if ( e' ≤ e ) then
        I = I'
    t = t + 1
od
```

3. FORCASTING THE EXCHANGE RATE

The proposed adaptive evolutionary strategy is used to evolve the function for forecasting the baht/us-dollar exchange rate. Using the data from Bank of Thailand during January – November 1998, 224 days. The result is validated using 10-fold cross validation method. The data is divided into two groups, 90% for training data and 10% for testing. The parameters of this experiment are 9 terms of function, mutation rate for mutation of functional form is 0.35 and 10,000 iterations for training.

The measure of correctness (*P*) is calculated from equation 3, where y_t is exchange rate at time *t*, *f*(*t*) is the value that is calculated from evolved function at time *t*, and *n* is a number of data.

$$P = 100 - e \quad (3)$$

$$e = \frac{\sum_{t=1}^{n} \left(\frac{|y_t - f(t)|}{y_t} \times 100 \right)}{n} \quad (4)$$

4. RESULT

From the experimental result, we choose the function that returns the minimum error on testing data for forecasting. This function is shown in equation 5.

23.5913 + 1.2262x / 20.9066x + 11.9073exp(-(((x-86.889879)/-97.964033))) -
-6.5593exp(-(((x-7.979729)/-14.378492))) + 17.8724exp(-(((x-11.885456)/30.668756))) -
39.1577tan(2.405826x) * -3.8903tan (0.840118x) * 4.1275x / 20.1120x (5)

The result of 10-fold cross validation is shown in **Table 2**.

Table 2. 10-fold cross validation result

folder	Training Data		Testing Data	
	RMS	P	RMS	P
1	1.36	97.15	7.28	87.52
2	1.28	97.72	2.40	95.52
3	1.43	97.87	1.87	95.99
4	1.73	97.03	0.76	98.37
5	2.60	95.03	5.09	88.93
6	**1.54**	**96.94**	**0.61**	**98.81**
7	2.77	94.23	2.86	93.19
8	1.49	97.28	1.79	95.85
9	2.17	96.82	0.87	98.45
10	1.38	97.60	0.80	98.13
Average	**1.77**	**96.77**	**2.43**	**95.08**

Figure 3 shows a forecasting function compared with an actual data.

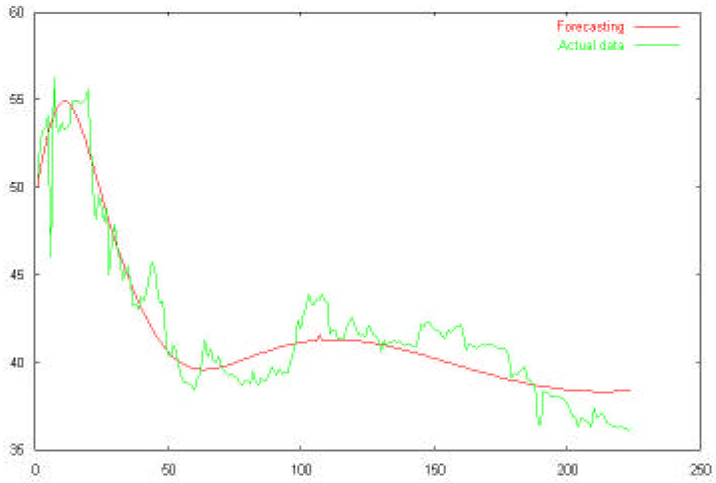

Figure 3. forecasting function and actual data

5. CONCLUSION

In this paper, we propose an adaptation of evolutionary strategies with evolved functional form. In the experiment, the proposed method is used to forecast the exchange rate of baht/us-dollar. Using 10-fold cross validation the error is less than 5%. The advantage of this method is that it is not necessary to determine the function before the forecasting task.

6. REFERENCES

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