

# CSE4312F12 Project Solution ROI

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## Note

- A customer elicitation session was held during class on Tuesday November 6, 2012. If you were not there sure to catch up with a fellow student who was there.
- This template is handed out *caveat emptor*. There may be errors and wrong information. It is ultimately your responsibility to elicit the correct requirements from the customer and to ensure that you satisfy the customer goals and specify correct output from the input.
- You are required to correct any errors or ambiguities in this template and use this template to produce your final requirements document.

## Revisions

| Date             | Revision | Description                  |
|------------------|----------|------------------------------|
| 10 October 2012  | 1.0      | Initial customer elicitation |
| 15 November 2012 | 2.0      | Initial Student solution     |
| 1 December 2012  | 3.0      | Final Student solution       |

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## 1 Context Diagram

The following diagram is the context diagram for the ROI system.

The monitored variables (which are the content of the CSV file, provided by the user), are :

- an header, which is composed of a required name, an optional description of the file and optional information about the customer (account number, email, address and phone number)
- the evaluation dates (*start* and *end*)
- the tuple data (*date*, *market value*, *cash flow*, *agent fees* and *benchmark*).

The format of the output is the following (whole input = everything between the earliest date and the latest date in the sequence of tuple data):

Name: ??

---

Whole input: yyyy-mm-dd to yyyy-mm-dd

TWR: ?? %

ROI: ?? %

Benchmark: ?? %

---

Evaluation Period: yyyy-mm-dd to yyyy-mm-dd

TWR: ?? %

ROI: ?? %

Benchmark: ?? %

---

If a data is not calculable, the user must read "undefined"  
(ex : "TWR: undefined").

The controlled variables are also a warning (if a calculation is not possible, if the evaluation period is not valid, or if the portfolio history has no name) and an error (if the CSV file is not valid).

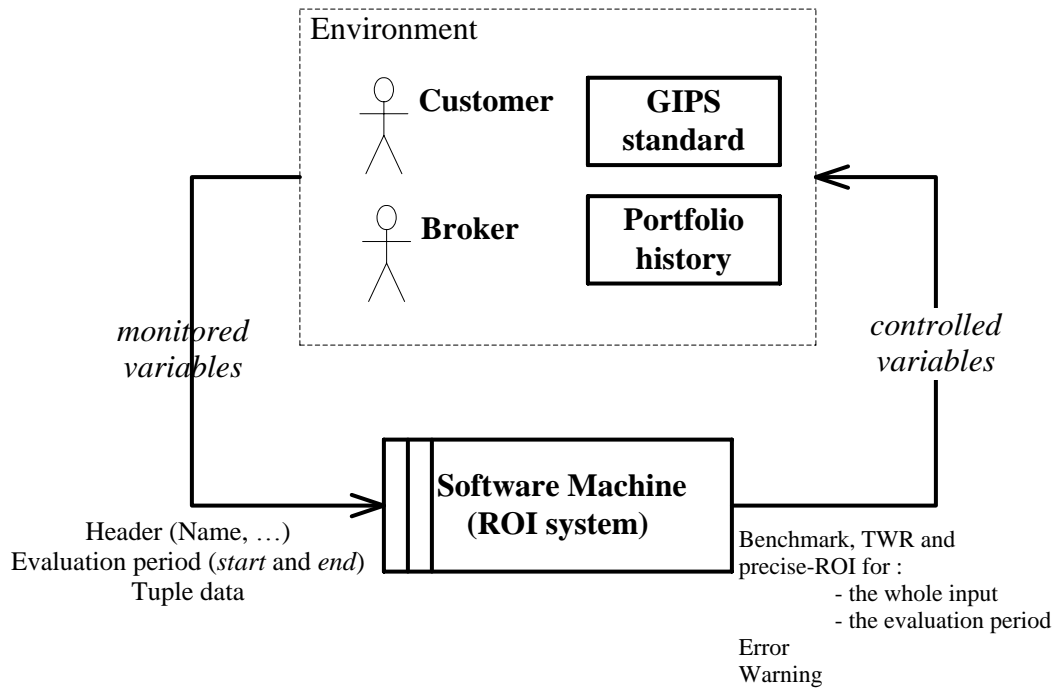


Figure 1: Context diagram for the ROI system

## 2 Dictionary

**Agent fees:** Money that the customer pays to the investment advisor to run the account.

**Benchmark:** Standard used as a point of reference for evaluating performance.

**Cash Flow:** Revenue or expense stream that changes a cash account over a given period.

**CSV:** Comma Separated Value file format used to store tabular data in which numbers and text are stored in plain-text form that can be easily written and read in a text editor.

**Customer:** The user of the software system.

**Evaluation Period:** a start and end date (provided by the user) for the portfolio history over which the return on investment is calculated.

**GIPS:** Global Investment Performance Standards

**Investment broker:** Runs the portfolio on behalf of the customer and supplies portfolio accounts.

**Portfolio statement:** List of all investments and current value.

**Portfolio History:** the historical data of investment performance over time that the customer stores about their investments as gleaned from their monthly or yearly investment accounts. Usually stored by customers in a CSV file (see Figure 1).

**ROI:** Return On Investment: Performance measure used to evaluate the efficiency of an investment.

**TWR:** Time Weighted Return: Measure of the compound rate of growth in a portfolio.

**Tuple data:** *date, market value, cash flow, agent fees and benchmark.*

### 3 E/R-descriptions

#### 3.1 E-descriptions

| ID | Description  | Comment |
|----|--|---------|
| E1 | Customers create and store a portfolio history, i.e. the historical data of their investment performance as determined from portfolio statements.      |         |
| E2 | Customers store their portfolio history as a CSV text file. CSV files may be prepared on editors of any operating system and encoded as ANSI or UTF-8. |         |

| Header of the CSV file |   |  |
|------------------------|---|--|
| E3.1                   | Every portfolio history has a name.   |  |
| E3.2                   | Optionally, every portfolio history has a description, account number, email, address, and phone number fields. |  |

| Evaluation period in the CSV file |   |  |
|-----------------------------------|---|--|
| E4.1                              | Optionally, every portfolio has an evaluation period that is between the start and end date of the historical performance data. | See Invariant 1 of TWR_ROI_CALCULATION (Fig. 11) |

|      |   |  |
|------|---|--|
| E4.2 | The start date and the end date must be in ISO format (yyyy-mm-dd). |  |
| E4.3 | The evaluation period is in range.                                  | See Invariant 1 of TWR_ROI_CALCULATION (Fig. 11) |

| Data in the CSV file |  |  |
|----------------------|--|--|
| E5.1                 | A portfolio history records investment performance in a non-empty sequence of tuple data, each tuple having the fields: date (required), market value (required), cash flow (optional), agent fees (optional) and benchmark (optional).            | See <i>tr</i> of TWR_ROI_CALCULATION (Fig. 11)   |
| E5.2                 | For each tuple, the dates must be in ISO format (yyyy-mm-dd).  |  |
| E5.3                 | When there is a customer contribution, the cash flow is a positive number. For a withdrawal, the number is negative.   |  |
| E5.4                 | Agent fees can be internal (deducted from within the portfolio) or external (additional amounts paid by the customer to the investment broker). The portfolio history reflects only external agent fees, always reported as a non-negative amount. |  |
| E5.5                 | Every data tuple (row in the CSV file) has a date and a non-negative market value.   | See Invariant 2 of TWR_ROI_CALCULATION (Fig. 11) |
| E5.6                 | Dates in the tuples are unique and ordered.  | See Invariant 3 of TWR_ROI_CALCULATION (Fig. 11) |
| E5.7                 | No withdrawal in the tuple data can be greater than the market value.  | See Invariant 4 of TWR_ROI_CALCULATION (Fig. 11) |
| E5.8                 | An account cannot grow from zero market value and cash flow.   | See Invariant 5 of TWR_ROI_CALCULATION (Fig. 11) |

|      |   |   |
|------|---|---|
| E5.9 | For each tuple, the market value plus cash-flow plus agent-fees must be non-zero. | See precondition 3 of feature <i>twr</i> of TWR_ROI_CALCULATION (Fig. 11) |
|------|---|---|

### 3.2 R-descriptions

| ID | Description   | Comment  |
|----|---|--|
| R1 | All return on investment calculations shall follow the GIPS standard. | See <i>twr</i> , <i>roi</i> , <i>benchmark</i> (Fig. 11) |

| Evaluation period |  |                     |
|-------------------|--|---------------------|
| R2                | Warning message: If no evaluation is provided or if the evaluation dates are not valid, then the following error message shall be displayed to the user: "Invalid evaluation period" | See Function tables |

| CSV file |   |                       |
|----------|---|-----------------------|
| R3.1     | Error message: If the CSV file is not valid (i.e. if any of the conditions mentioned above do not hold), then the following error message shall be displayed to the user: "Invalid file". | See Function tables   |
| R3.2     | Warning message: If the CSV file does not contain a name, then the following error message shall be displayed to the user: "Incomplete file: absence of name".                            | See Function table 20 |

| Calculation of the TWR |   |                       |
|------------------------|---|-----------------------|
| R4.1                   | The system shall provide two TWRs (if each one is calculable) : one for the evaluation period, and one for the whole input. | See Function table 17 |
| R4.2                   | The TWRs shall be rounded to two decimal places.  |                       |

|      |   |  |
|------|---|--|
| R4.3 | If the evaluation period is less than a year, then the TWR shall be reported in absolute terms as a percentage return (i.e. it is not annualized). If the evaluation period is a year or more, then the TWR is annualized to a percentage per year. | See postcondition of <i>annual_compounded_TWR</i> of TWR_ROI_CALCULATION (Fig. 11) |
| R4.4 | The annualized TWR shall be reported as a percentage.   | See <i>annual_compounded_TWR</i> of TWR_ROI_CALCULATION (Fig. 11)                  |
| R4.5 | Agent fees are treated like a deposit (the agent fees are <u>added</u> to the market value and the cash flow).  | See <i>twr</i> of TWR_ROI_CALCULATION (Fig. 11)                                    |
| R4.6 | Warning message: If the TWR is not calculable, then a warning message shall be displayed to the user.   | See Function table 17  |

| Calculation of the ROI |   |   |
|------------------------|---|---|
| R5.1                   | The system shall provide two ROIs : one for the evaluation period, and one for the whole input. | See Function table 18                           |
| R5.2                   | The ROIs shall be rounded to two decimal places.  |   |
| R5.3                   | The ROI shall be reported as a percentage.  | See <i>roi</i> of TWR_ROI_CALCULATION (Fig. 11) |
| R5.4                   | Agent fees are treated like a deposit (the agent fees are <u>added</u> to the cash flow).       | See <i>roi</i> of TWR_ROI_CALCULATION (Fig. 11) |

| Calculation of the Benchmark |   |                       |
|------------------------------|---|-----------------------|
| R6.1                         | The system shall provide two benchmarks (if each one is calculable) : one for the evaluation period, and one for the whole input. | See Function table 19 |
| R6.2                         | The benchmarks shall be rounded to two decimal places.  |                       |



---

|      |  |   |
|------|--|---|
| R6.3 | The benchmark shall be reported as a compounded ROI, if the benchmark figures are available for the evaluation period. | See <i>benchmark</i> of TWR_ROI_CALCULATION (Fig. 11) |
| R6.4 | Warning message: If the benchmark is not calculable, then a warning message shall be displayed to the user.            | See Function table 19                                 |

#### **4 Mathematical model**

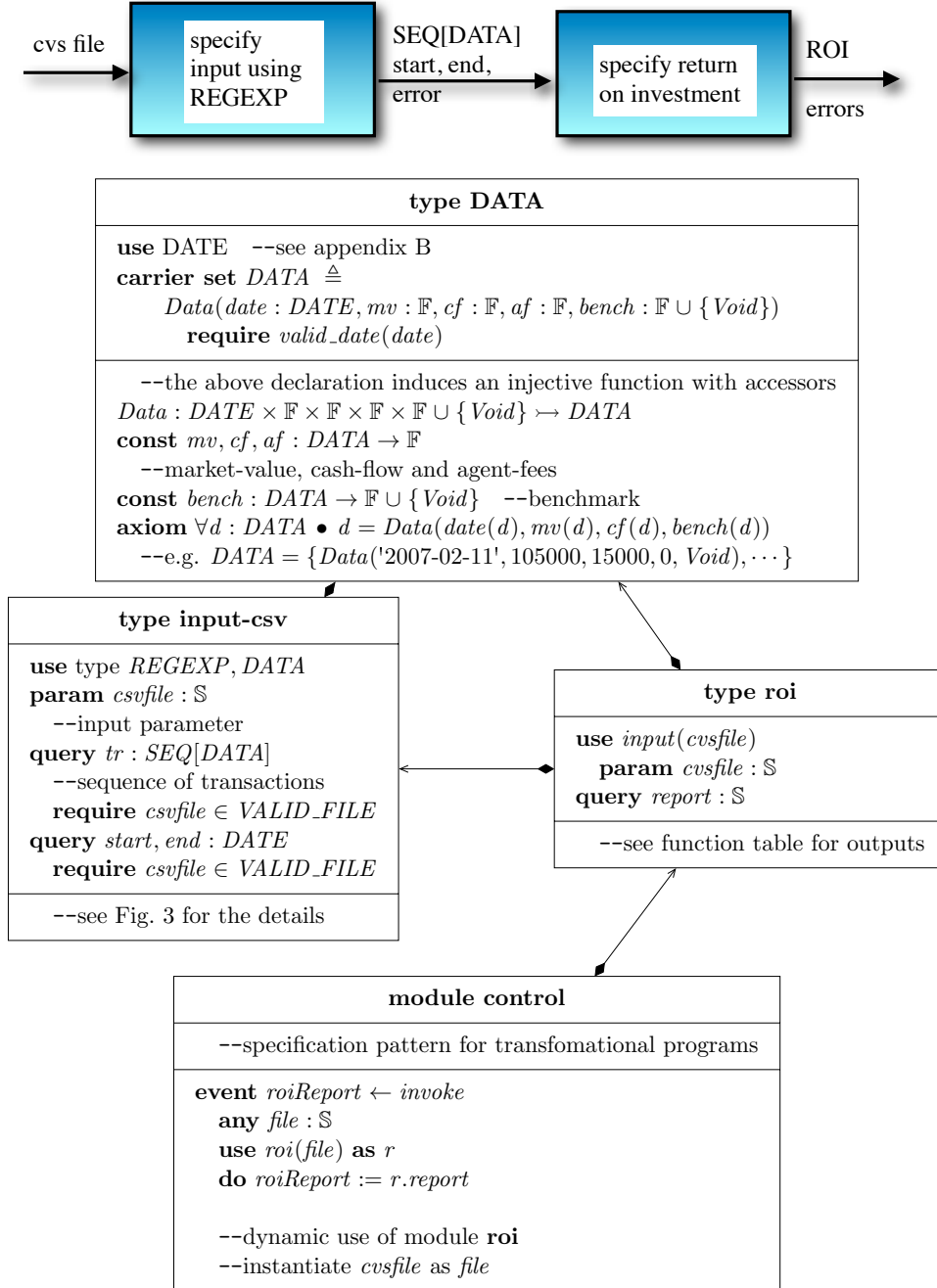


Figure 2: Module specification of return on investment

| type input-csv  |
|---|
| <pre> <b>use</b> type <i>REGEXP</i>, <i>DATA</i>, <i>DATE</i>  --we let <math>\epsilon = \{“”\}</math>, <math>\text{eol} = \{\backslash\text{n}\}</math> etc. <b>carrier set</b> <i>DATA</i> <math>\triangleq \text{Data}(\text{date} : \text{DATE}, \text{mv} : \mathbb{F}, \text{cf} : \mathbb{F}, \text{af} : \mathbb{F}, \text{bench} : \mathbb{F} \cup \{\text{Void}\})</math> <b>param</b> <i>csvfile</i> : <math>\mathbb{S}</math>  --input parameter <b>query</b> <i>tr</i> : <i>SEQ</i>[<i>DATA</i>]  --sequence of transactions defined by axiom below   <b>require</b> <i>csvfile</i> <math>\in \text{VALID\_FILE}</math> <b>query</b> <i>start</i>, <i>end</i> : <i>DATE</i>   <b>require</b> <i>csvfile</i> <math>\in \text{VALID\_FILE}</math> </pre>   |
| <pre> <b>const</b> <i>VALID\_FILE</i> : <i>REGEXP</i>   <math>\triangleq \text{HEADER} \cdot \text{PARAMETERS} \cdot \text{eol} \cdot \text{ROW} \cdot *(\text{eol} \cdot \text{ROW}) \cdot *(",   \text{eol})</math> <b>const</b> <i>HEADER</i> : <i>REGEXP</i>   <math>\triangleq *( \text{HLINE} \cdot \text{eol} )</math> <b>const</b> <i>HLINE</i> : <i>REGEXP</i>   <math>\triangleq *(\Sigma \backslash \text{eol}) \backslash ( \text{EV\_PER} \cdot * \Sigma )</math> <b>const</b> <i>PARAMETERS</i> : <i>REGEXP</i>   <math>\triangleq \text{EV\_PER} \cdot \text{DATE\_STR} \cdot \text{"\_to\_"} \cdot \text{DATE\_STR} \cdot * ", " \cdot \text{eol} \cdot \text{COL\_HEAD}</math> <b>const</b> <i>COL\_HEAD</i> : <i>REGEXP</i>   <math>\triangleq + ", " \cdot \text{eol} \cdot</math>     "Transaction\_Date,Market\_Value,Cash\_Flow,Agent\_Fees,Benchmark" <math>\cdot * ", "</math> <b>const</b> <i>EV\_PER</i> : <i>REGEXP</i> <math>\triangleq \text{"Evaluation\_Period:."}</math> <b>const</b> <i>ROW</i> : <i>REGEXP</i>   <math>\triangleq (\text{DATE\_STR} \cdot ", " \cdot \text{FLOAT} \cdot ", " \cdot (\text{FLOAT}   \epsilon) \cdot ", " \cdot (\text{FLOAT}   \epsilon) \cdot</math>     ", " <math>\cdot (\text{FLOAT} \cdot \text{"\%"}   \epsilon) \cdot * ", "</math> <b>const</b> <i>s2d</i> : <i>DATE\_STR</i> <math>\rightarrow \text{DATE}</math>  --see birthday book for <i>DATE</i> <b>const</b> <i>s2f</i> : <i>FLOAT</i> <math>\rightarrow \mathbb{F}</math>  --deferred, <i>FLOAT</i> is the string version of <math>\mathbb{F}</math> <b>const</b> <i>f2s</i> : <math>\mathbb{F} \rightarrow \text{FLOAT}</math>  --deferred, see your favourite programming language <b>const</b> <i>d2s</i> : <i>DATE</i> <math>\rightarrow \text{DATE\_STR}</math>  --deferred <b>const</b> <i>s2optf</i>[<i>G</i>] : <math>(\text{FLOAT}   \epsilon) \times G \rightarrow \mathbb{F} \cup G</math>  --string-to-optional float   <b>where</b> <math>\forall G \bullet s2optf \in (\text{FLOAT}   \epsilon) \times G \rightarrow \mathbb{F} \cup G</math>   --parameter <i>G</i> is a set such as <math>\{\text{Void}\}</math> or a default value such as <math>\{0\}</math> <b>const</b> <i>f</i> : <i>ROW</i> <math>\rightarrow \text{DATA}</math> <b>dummy</b> <i>w</i> : <i>ROW</i> and <i>s</i><sub>0</sub>, <i>s</i><sub>1</sub>, <i>s</i><sub>2</sub>, <i>s</i><sub>3</sub> : <math>\mathbb{S}</math> <b>axiom</b> 1:  --definition of function <i>f</i> that maps a row string to data   <math>w \in (d2s(d) \cdot ", " \cdot s_0 \cdot ", " \cdot s_1 \cdot ", " \cdot s_2 \cdot ", " \cdot s_3 \cdot * ", ")</math>   <math>\wedge (s_4 \cdot \text{"\%"} = s_3 \vee s_4 = s_3 = \epsilon)</math>   <math>\Rightarrow f(w) = \text{Data}(d, s2f(s_0), s2optf(s_1, 0), s2optf(s_2, 0), s2optf(s_4, \text{Void}))</math> <b>query</b> <i>error</i> : <math>\mathbb{B} \triangleq \text{textfile} \notin \text{VALID\_FILE}</math>  --definition of <i>tr</i>, <i>start</i>, <i>end</i> <b>axiom</b> 2:  --definition of <i>tr</i>, <i>start</i>, <i>end</i>   <i>csvfile</i> <math>\in \text{VALID\_FILE} \Rightarrow</math>   <math>(\exists h, \text{foot}, s, e : \mathbb{S}; \text{data} : \text{SEQ}[\text{ROW}]</math>     <math>h \in \text{HEADER} \cdot \text{EV\_PER} \cdot s \cdot \text{"\_to\_"} \cdot e \cdot * ", " \cdot \text{eol} \cdot \text{COL\_HEAD}</math>   <math>\wedge \text{data} \in \text{SEQ}[\text{ROW}]</math>   <math>\wedge \text{end} \in *('   \text{eol})</math>   <math>\wedge \text{textfile} \in h \cdot (\cdot   0 \leq i &lt; \# \text{data} \bullet \text{eol} \cdot \text{data}(i)) \cdot \text{foot}</math>   <math>\bullet \text{tr} = (\cdot   0 \leq i &lt; \# \text{data} \bullet &lt; f(\text{data}(i)) &gt;</math>   <math>\wedge (\text{start} = s2d(s)) \wedge (\text{end} = s2d(e))</math>   ) </pre> |

Figure 3: Type input-csv

### TWR\_ROI\_CALCULATION

**--input** (*input.csv*)

*tr*: SEQ[DATA]

--sequence of data [*date*, *market\_value*, *cash\_flow*, *agent\_fees*, *benchmark*]

--*tr.domain* = {1,2,...,*tr.count*}

*count*: INTEGER  $\triangleq$  *tr.count*

*dates*: SET[DATE]  $\triangleq$  {*t* ∈ *tr* • *t.date*}

*start* : DATE  $\triangleq$  *tr*[1] --first date of the file

*end* : DATE  $\triangleq$  *tr*[*count*] --last date of the file

*duration*: VALUE  $\triangleq$  *days*(*end* - *start*) ÷ (365.2422)

--years between *start* and *end* calculated by days

--*days*(x) similar to Excel

**--output calculation** (*input.out.csv*)

*di* (*d*:DATE): INTEGER

--index into sequence of transaction for date *d*

**require** *d* ∈ *dates*

**ensure** *Result* ∈ *tr.domain* ∧ *tr*[*Result*].*date*=*d*

TODO: DANS REQUIRE I VARIE DANS L'INTERVALLE D'INDICE  
DEFINIT PAR S ET E

IL FAUT VERIFIER QUE CE SOIT BIEN CA DANS LES E/R

--TWR for the period *s* .. *e*

*twr* (*s*, *e*: DATE): VALUE

**require**

*s*, *e* ∈ *dates*

*e* > *s*

∀*i* ∈ *di*(*s*)+1..*di*(*e*) • *tr*[*i*-1].*mv* + *tr*[*i*-1].*cf* + *tr*[*i*-1].*af* ≠ 0

**ensure**

$Result \triangleq (\Pi i:INTEGER \mid di(s) < i \leq di(e) \bullet wealth(i)) - 1$   
 where  $wealth(i) \triangleq tr[i].mv \div (tr[i-1].mv + tr[i-1].cf + tr[i-1].af)$

TODO: SUPPRIMER LA VARIABLE DURATION ET  
 REMPLACER PAR LA BONNE CHOISE

*annual\_compounded\_TWR* (*s*, *e*: DATE): VALUE

**ensure**

$(duration \geq 1) \Rightarrow Result = ((1 + twr(s, e))^{1 \div duration} - 1) * 100$

$(duration < 1) \Rightarrow Result = twr(s, e) * 100$

TODO: IL FAUT RETIRER DES E-R DESCRIPTION QUE  
 AF EST UN DEPOSIT AILLEUR QUE POUR LE TWR

TODO: VERIFIER QUE LE + POUR LES AGENT FEES  
 CI DESSOUS EST CORRECT, DANS LE CODE JE L'AI  
 CHANGE EN -

*roi* (*s*, *e*: DATE): VALUE

**require**

$s, e \in dates$

$e > s$

**ensure**

$(tr[m].mv + tr[m].cf) * (1 + Result \div 100)^{days(e-s) \div 365.2422}$

$+ (\sum i \mid m < i < n \bullet (tr[i].cf + tr[i].af)) * (1 + Result \div 100)^{days(e-tr[i].date) \div 365.2422} - tr[n].mv = 0$

**where**

$m = di(s)$

$n = di(e)$

*year* (*d*: DATE): INTEGER

**require**

$d = "yyyy - mm - dd"$

**ensure**

$Result = yyyy$

*mon* (*d*: DATE): INTEGER

**require**

$d = "yyyy - mm - dd"$

**ensure**

$Result = mm$

$day(d : DATE): INTEGER$

**require**

$d = "yyyy - mm - dd"$

**ensure**

$Result = dd$

TODO FAIRE LES FONCTION TABLE POUR MIN ET MAX

TODO VOIR POUR LE REQUIRE DE MIN ET MAX

$\uparrow (f, s: DATE): DATE$

**require**

**ensure**

$\langle\langle \text{see table...} \rangle\rangle$

$\downarrow (f, s: DATE): DATE$

**require**

**ensure**

$\langle\langle \text{see table...} \rangle\rangle$

TODO FAIRE ET NUMEROTER LA FUNCTION TABLE

DE LA FCT SUIVANTE

$at (d: DATE): DATA$

**ensure**

$\langle\langle \text{see table...} \rangle\rangle$

TODO: FAIRE UN CHECK AVANT (DANS LE MAIN)

POUR SAVOIR SI S ET E SONT DANS DATES

$bm\_calculable (s, e: DATE): BOOL$

**require**

$s, e \in dates$

$s \neq e$

$s < e$

**ensure**

$Result = at[end \downarrow a].bench \neq void$

$\wedge (\forall d \in DATE | mon(d) = day(d) = 1 \wedge year(s) < year(d) \leq year(e)$

$\bullet at[d].bench \neq void)$

$$\wedge((C \wedge at[e].bench \neq void) \vee (\neg C \wedge at[end \downarrow b].bench \neq void))$$

**where**

$$a = \text{"year}(s) + 1 - 01 - 01"$$

$$b = \text{"year}(e) + 1 - 01 - 01"$$

$$C = (mon(e) = 1 \wedge day(e) = 1)$$

TODO RAJOUTER LA FUNCTION TABLE

--the function below return a set of DATA with a benchmark  $\neq$  void

*bm\_seq* (*s*, *e*: DATE): SEQ[DATA]

**require**

$$s, e \in \text{dates}$$

$$bm\_calculable(s, e)$$

**ensure**

$$Result = (\oplus i | di(s) < i < di(e) \wedge tr[i].bench \neq void \bullet < tr[i] >)$$

$$\oplus < t >$$

**where**

$$t = << \text{see table ...}>>$$

*po*(*s*, *e*, *d1*, *d2*: DATE): VALUE

**require**

$$d1 \neq d2$$

**ensure**

$$Result \triangleq \text{days}(d2 \downarrow e - d1) \div \text{days}(d2 - \text{"year}(d1) - 01 - 01")$$

*bm\_final\_value*(*s*, *e*: DATE): VALUE

**require**

$$s, e \in \text{dates}$$

$$bm\_calculable(s, e)$$

**ensure**

$$Result \triangleq$$

$$tr[m].mv * (\Pi i, seq, t | seq = bm\_seq(s, e) \wedge a \oplus seq \wedge 1 \leq i \leq \#seq$$

$$\wedge t = seq[i] \bullet t.bench^{po(s, e, seq[i-1].date, t.date)})$$

$$+ (\Sigma k | m \leq k < n \bullet (tr[k].cf - tr[k].af) *$$

$$(\Pi i, seq, t | seq = bm\_seq(tr[k].date, e) \wedge b(k) \oplus seq \wedge 1 \leq i \leq \#seq$$

$$\wedge t = seq[i] \bullet t.bench^{po(s, e, seq[i-1].date, t.date)}))$$

**where**

$$m = di(s)$$



```

n = di(e)
--a defines seq[0] in the first product
--b(k) defines seq[0] in the second product
a = < (s, 0, 0, 0, void) >
b(k) = < (tr[k].date, 0, 0, 0, void) >

```

EST-CE QUE C'EST NORMAL QU'IL N'Y AI PAS DE AF DANS BENCHMARK?

*benchmark*(s, e: DATE): VALUE

**require**

```

s, e ∈ dates
bm_calculable(s, e)

```

**ensure**

```

tr[m].mv * (1 + Result ÷ 100)days(e-s)÷365.2422
+ (Σk|m ≤ k < n tr[k].cf *
  (1 + Result ÷ 100)days(e-tr[k].date)÷365.2422) - FV = 0

```

**where**

```

m = di(s)
n = di(e)
FV ≜ bm_final_value(s, e)

```

### Invariants

- (1)  $(start < end) \wedge (start, end \in dates)$   
--metadata evaluation period is in range and valid
- (2)  $\forall t \in tr \bullet t.date \neq Void \wedge t.mv \geq 0$   
--every row has a date and a non-negative market value
- (3)  $\forall i \in 2..count \bullet tr[i].date > tr[i-1].date$   
--date are unique and ordered
- (4)  $\forall t \in tr \bullet t.mv + t.cf \geq 0$   
--Cannot withdraw more than the market value
- (5)  $\forall i \in 2..count \mid tr[i-1].mv = 0 \wedge tr[i-1].cf = 0 \bullet tr[i].mv = 0$   
--account coannot grow from zero market value and cash flow

Table 11: Mathematical model for the ROI system

TODO : A CHECKER !!! + TITRE

| fi, se : DATE       |  | Min | Max |
|---------------------|--|-----|-----|
| year(fi) < year(se) |  | fi  | se  |
| year(fi) > year(se) |  | se  | fi  |
| year(fi) = year(se) | mon(fi) < mon(se)                      | fi  | se  |
|                     | mon(fi) > mon(se)                      | se  | fi  |
|                     | mon(fi) = mon(se)    day(fi) < day(se) | fi  | se  |
|                     | mon(fi) = mon(se)    day(fi) ≥ day(se) | se  | fi  |

Table 12: Function table for ROI system (calculation of the benchmarks)

|           |                        | at(d)   |
|-----------|------------------------|---|
| d ∈ dates |                        | $\exists! i \mid 1 \leq i \leq \text{count} \bullet \text{Result} = \text{tr}[i] \wedge \text{Result.date} = d$ |
| d ∉ dates | mon(d)=1 ∧ day(d)=1    | Result = (d,0,0,0,void)   |
|           | ¬(mon(d)=1 ∧ day(d)=1) | null  |

Table 13: Function table for ROI system (calculation of the ROIs)

#### 4.1 Function tables

##### 4.1.1 Abbreviations, conditions and messages

| Abbreviation | Description  |
|--------------|--|
| first        | $tr[1].date$   |
| last         | $tr[tr.count].date$  |
| a_c_TWR      | annual_compounded_TWR<br>(see TWR_ROI_CALCULATION (Fig. 11)) |
| b            | benchmark (see TWR_ROI_CALCULATION (Fig. 11))                |

| Condition   | Description  |
|-------------|--|
| C1          | $\forall i \in 2..count \bullet tr[i-1].mv + tr[i-1].cf + tr[i-1].af \neq 0$             |
| C2          | $\forall i \in di(start)+1..di(end) \bullet tr[i-1].mv + tr[i-1].cf + tr[i-1].af \neq 0$ |
| C3          | benchmark_calculable(first,last)<br>(see TWR_ROI_CALCULATION (Fig. 11))                  |
| C4          | benchmark_calculable(start,end)<br>(see TWR_ROI_CALCULATION (Fig. 11))                   |
| Start_Valid | $(start \in dates \cup \{null\}) \wedge (start \text{ in ISO format})$                   |
| End_Valid   | $(end \in dates \cup \{null\}) \wedge (end \text{ in ISO format})$                       |
| Name        | $(csvfile.name = null)$  |

| Message | Description                                       |
|---------|---|
| E       | "Invalid file"                                    |
| W       | "Invalid evaluation period"                       |
| W1      | "The TWR for the whole input is not calculable"   |
| W2      | "The TWR's are not calculable"                    |
| W3      | $W + W1$  |
| W4      | "Benchmark for the whole input is not calculable" |
| W5      | "The benchmarks are not calculable"               |
| W6      | $W + W4$  |
| W7      | "Incomplete file: absence of name"                |

## 4.1.2 Calculation of the TWRs

|             |  | Error | Warning | TWR<br>(whole input) | TWR<br>(evaluation period) |
|-------------|--|-------|---------|----------------------|----------------------------|
| Valid_CSV   | $\neg(\text{Start\_Valid}) \vee \neg(\text{End\_Valid}) \vee \text{end} \leq \text{start}$ | —     | W       | a_c.TWR(first,last)  | —                          |
|             | $\neg C1$  | —     | W3      | —                    | —                          |
|             | $\text{Start\_Valid} \wedge \text{End\_Valid} \wedge \text{end} > \text{start}$            | —     | —       | a_c.TWR(first,last)  | a_c.TWR(start,end)         |
|             | $\neg C1$  | —     | W1      | —                    | a_c.TWR(start,end)         |
| Invalid_CSV | C2   | —     | W2      | —                    | —                          |
|             | $\neg C2$  | —     | —       | —                    | —                          |
|             | E  | E     | —       | —                    | —                          |

Table 17: Function table for ROI system (calculation of the TWRs)

### 4.1.3 Calculation of the ROIs

|             | Error | Warning | ROI (whole input) | ROI (evaluation period) |
|-------------|-------|---------|-------------------|-------------------------|
| Valid_CSV   | —     | W       | —                 | —                       |
|             | —     | —       | roi(first, last)  | roi(start, end)         |
| Invalid_CSV | E     | —       | —                 | —                       |

Table 18: Function table for ROI system (calculation of the ROIs)

## 4.1.4 Calculation of the benchmarks

|             |  | Error | Warning | Benchmark<br>(whole input)     | Benchmark<br>(evaluation period) |
|-------------|--|-------|---------|--------------------------------|----------------------------------|
| Valid_CSV   | $\neg(\text{Start\_Valid}) \vee$<br>$\neg(\text{End\_Valid}) \vee$<br>$\text{end} \leq \text{start}$ | —     | W       | $b(\text{first}, \text{last})$ | —                                |
|             | $\neg C3$  | —     | W6      | —                              | —                                |
|             | $\text{Start\_Valid} \wedge$<br>$\text{End\_Valid} \wedge$<br>$\text{end} > \text{start}$            | —     | —       | $b(\text{first}, \text{last})$ | $b(\text{start}, \text{end})$    |
|             | $\neg C3$  | —     | W4      | —                              | $b(\text{start}, \text{end})$    |
| Invalid_CSV | $C4$   | —     | W5      | —                              | —                                |
|             | $\neg C4$  | —     | —       | —                              | —                                |
|             |  | E     | —       | —                              | —                                |

Table 19: Function table for ROI system (calculation of the benchmarks)

#### 4.1.5 Name of the portfolio history

|       |         |
|-------|---------|
|       | Warning |
| Name  | —       |
| ¬Name | W7      |

Table 20: Function table for ROI system (name of the portfolio history)

### 5 Acceptance tests

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T1 - test_date.invalid.csv   |
| <b>Description</b>            | Verify that an invalid date raises an error.                             |
| <b>Requirement IDs tested</b> | R3.1   |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.                                     |
| <b>Action</b>                 | Execute the ROI system on the CSV file                                   |
| <b>Consequences</b>           | Output : "Error: Invalid file."  |
| <b>Test Case ID</b>           | T2 - test_date.invalid_February.csv                                      |
| <b>Description</b>            | Verify that an invalid date (because of the leap years) raises an error. |
| <b>Requirement IDs tested</b> | R3.1   |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.                                     |
| <b>Action</b>                 | Execute the ROI system on the CSV file                                   |
| <b>Consequences</b>           | Output : "Error: Invalid file."  |

|                               |   |
|-------------------------------|---|
| <b>Test Case ID</b>           | T3 - test_tuple_without_date.csv                    |
| <b>Description</b>            | Verify that a tuple without a date raises an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.5)                               |
| <b>Type</b>                   | Negative  |
| <b>Initial State</b>          | A directory containing the CSV file.                |
| <b>Action</b>                 | Execute the ROI system on the CSV file              |
| <b>Consequences</b>           | Output : "Error: Invalid file."                     |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T4 - test_negative_market_value.csv                  |
| <b>Description</b>            | Verify that a negative market value raises an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.5)                                |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.                 |
| <b>Action</b>                 | Execute the ROI system on the CSV file               |
| <b>Consequences</b>           | Output : "Error: Invalid file."                      |

|                               |   |
|-------------------------------|---|
| <b>Test Case ID</b>           | T5 - test_dates_non_unique.csv                            |
| <b>Description</b>            | Verify that two tuples with the same date raise an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.6)                                     |
| <b>Type</b>                   | Negative  |
| <b>Initial State</b>          | A directory containing the CSV file.                      |
| <b>Action</b>                 | Execute the ROI system on the CSV file                    |
| <b>Consequences</b>           | Output : "Error: Invalid file."                           |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T6 - test_dates_non_ordered.csv                          |
| <b>Description</b>            | Verify that tuples which are not ordered raise an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.6)                                    |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.                     |
| <b>Action</b>                 | Execute the ROI system on the CSV file                   |
| <b>Consequences</b>           | Output : "Error: Invalid file."                          |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T7 - test_withdraw.csv   |
| <b>Description</b>            | Verify that a withdraw which is greater than the market value raises an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.7)  |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.   |
| <b>Action</b>                 | Execute the ROI system on the CSV file   |
| <b>Consequences</b>           | Output : "Error: Invalid file."  |



|                               |   |
|-------------------------------|---|
| <b>Test Case ID</b>           | T8 - test_grow.csv  |
| <b>Description</b>            | Verify that an account which grow from zero market value and cash flow raises an error. |
| <b>Requirement IDs tested</b> | R3.1 (regarding E5.8)   |
| <b>Type</b>                   | Negative  |
| <b>Initial State</b>          | A directory containing the CSV file.  |
| <b>Action</b>                 | Execute the ROI system on the CSV file  |
| <b>Consequences</b>           | Output : "Error: Invalid file."   |

|                               |   |
|-------------------------------|---|
| <b>Test Case ID</b>           | T9 - sample.csv   |
| <b>Description</b>            | Verify that the system works well for a simple example.   |
| <b>Requirement IDs tested</b> | R1, R4.1, R4.2, R4.3, R4.4, R5.1, R5.2, R5.3, R6.1, R6.2, R6.3  |
| <b>Type</b>                   | Positive  |
| <b>Initial State</b>          | A directory containing the CSV file.  |
| <b>Action</b>                 | Execute the ROI system on the CSV file  |
| <b>Consequences</b>           | Name: Roy Bostock<br>Whole input: 2007-01-01 to 2009-04-01<br>TWR: 82.62 %<br>ROI: 76.26 %<br>Benchmark: 40.45 %<br>Evaluation Period: 2007-01-01 to 2008-01-01<br>TWR: 26.88 %<br>ROI: 26.54%<br>Benchmark: 15.01% |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T10 - sample_warning_invalid_eval_period.csv   |
| <b>Description</b>            | Verify that the system provides the calculations for the whole input but not for the evaluation period (evaluation period not valid).  |
| <b>Requirement IDs tested</b> | R1, R2, R4.1, R4.2, R4.3, R4.4, R5.1, R5.2, R5.3, R6.1, R6.2, R6.3   |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.   |
| <b>Action</b>                 | Execute the ROI system on the CSV file   |
| <b>Consequences</b>           | Warning: Invalid evaluation period<br>Name: Roy Bostock<br>Whole input: 2007-01-01 to 2009-04-01<br>TWR: 82.62 %<br>ROI: 76.26 %<br>Benchmark: 40.45 %<br>Evaluation Period: undefined<br>TWR: undefined<br>ROI: undefined<br>Benchmark: undefined |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T11 - sample_warning_name.csv  |
| <b>Description</b>            | Verify that the system provides the calculations for the whole input and for the evaluation period, but provides a warning because of the absence of name.   |
| <b>Requirement IDs tested</b> | R1, R3.2, R4.1, R4.2, R4.3, R4.4, R5.1, R5.2, R5.3, R6.1, R6.2, R6.3   |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.   |
| <b>Action</b>                 | Execute the ROI system on the CSV file   |
| <b>Consequences</b>           | Warning: Incomplete file: absence of name<br>Name: undefined<br>Whole input: 2007-01-01 to 2009-04-01<br>TWR: 82.62 %<br>ROI: 76.26 %<br>Benchmark: 40.45 %<br>Evaluation Period: 2007-01-01 to 2008-01-01<br>TWR: 26.88 %<br>ROI: 26.54%<br>Benchmark: 15.01% |

|                               |  |
|-------------------------------|--|
| <b>Test Case ID</b>           | T12 - sample_warning_no_eval_period.csv  |
| <b>Description</b>            | Verify that the system provides the calculations for the whole input but not for the evaluation period (evaluation period not given).  |
| <b>Requirement IDs tested</b> | R1, R2, R4.1, R4.2, R4.3, R4.4, R5.1, R5.2, R5.3, R6.1, R6.2, R6.3   |
| <b>Type</b>                   | Negative   |
| <b>Initial State</b>          | A directory containing the CSV file.   |
| <b>Action</b>                 | Execute the ROI system on the CSV file   |
| <b>Consequences</b>           | Warning: Invalid evaluation period<br>Name: Roy Bostock<br>Whole input: 2007-01-01 to 2009-04-01<br>TWR: 82.62 %<br>ROI: 76.26 %<br>Benchmark: 40.45 %<br>Evaluation Period: undefined<br>TWR: undefined<br>ROI: undefined<br>Benchmark: undefined |

**6 Requirements Traceability matrix**

| Requirement ID | Test Case IDs                  |
|----------------|--------------------------------|
| R1             | T9, T10, T11, T12              |
| R2             | T10, T12                       |
| R3.1           | T1, T2, T3, T4, T5, T6, T7, T8 |
| R3.2           | T11                            |
| R4.1           | T9, T10, T11, T12              |
| R4.2           | T9, T10, T11, T12              |
| R4.3           | T9, T10, T11, T12              |
| R4.4           | T9, T10, T11, T12              |
| R4.5           |                                |
| R4.6           |                                |
| R5.1           | T9, T10, T11, T12              |
| R5.2           | T9, T10, T11, T12              |
| R5.3           | T9, T10, T11, T12              |
| R5.4           |                                |
| R6.1           | T9, T10, T11, T12              |
| R6.2           | T9, T10, T11, T12              |
| R6.3           | T9, T10, T11, T12              |
| R6.4           |                                |

## A REGEXP

A set of strings is used as the model for regular expressions. We use prefix operators for the Kleene closure (e.g.  $*x$  where  $x$  is a regular expression such as  $\{\text{'hello'}\}$ ) and iteration at least one or more (e.g.  $+x$ ) rather than suffix operators. Note that where there is no confusion we use  $\text{'hello'}$  instead of  $\{\text{'hello'}\}$  where the set is a singleton.

We may use type REGEXP to specify a *FLOAT\_STRING* as follows.

$$FLOAT\_STRING = '+' Inf \quad (1)$$

$$| '-' Inf \quad (2)$$

$$| NaN \quad (3)$$

$$| ('-' | '+' | \epsilon) \cdot (*d \cdot '.' | \epsilon) \cdot *d \cdot (('e' \cdot ('-' | \epsilon) \cdot^+ d) | \epsilon) \quad (4)$$

$$d = '0' | '1' | \dots | '9' \quad (5)$$

In the above we use the convention that  $'e'$ , for example, really stands for the single set  $\{ 'e' \}$ .

| type REGEXP  |
|--|
| <b>carrier set</b> $REGEXP$ --set of all regular string expressions<br><b>axiom</b> $REGEXP \subseteq \mathbb{P}(\mathbb{S})$<br><b>carrier set</b> $\Sigma \triangleq \{“0”, “1”, “2”, \dots, “a”, “b”, \text{ etc.}, \text{ all printing characters}\}$  |
| <b>dummy</b> $x, y, z : REGEXP$<br><b>dummy</b> $s, t, u : \mathbb{S}$<br><b>axiom</b> $\forall s \in \Sigma \bullet \{s\} \in REGEXP$<br><b>const</b> $0 : REGEXP \triangleq \{\}$ --zero is the unit element of alternation<br><b>const</b> $1 : REGEXP \triangleq \{“”\}$ --1 is the unit element of concatenation<br>--we also use $\epsilon$ instead of 1<br><b>const infix</b> $“ ” : REGEXP \times REGEXP \rightarrow REGEXP$<br>--alternation<br><b>const infix</b> $“.” : REGEXP \times REGEXP \rightarrow REGEXP$<br>--concatenation<br><b>const prefix</b> $“*” : REGEXP \times REGEXP \rightarrow REGEXP$<br>--iteration zero or more times<br><b>const prefix</b> $“+” : REGEXP \times REGEXP \rightarrow REGEXP$<br>--iteration one or more times<br><b>axiom</b> $s \in x y \equiv s \in x \vee s \in y$<br><b>theorem</b> $x 0 = 0 x = x$<br><b>axiom</b> $s \in x \cdot y \equiv (\exists t, u   s = t \cdot u \bullet t \in x \wedge u \in y)$<br>--note that $t \cdot u$ is concatenation over $SEQ[\mathbb{S}]$<br><b>theorem</b> $1 \cdot x = x \cdot 1 = 1$ --1 is the identity of concatenation<br><b>const infix</b> $“^” : REGEXP \times \mathbb{N} \rightarrow REGEXP$<br>--use this operator by raising the second argument like an exponent<br><b>axiom</b> $x^n = (\cdot i   0 \leq i \leq n \bullet x)$ --concatenation quantifier<br>--e.g. $x^3 = x \cdot x \cdot x$<br><b>theorem</b> $x^0 = 1$<br><b>axiom</b> $s \in *x \equiv (\exists n : \mathbb{N} \bullet s \in x^n)$<br><b>axiom</b> $s \in +x \equiv (\exists n : \mathbb{N}_1 \bullet s \in x^n)$ |

Figure 4: Type REGEXP for regular expressions over printing characters

## B DATE

The specification of the date module is provided on the following page.

| type DATE  |  |
|--|--|
| <b>carrier set</b> DATE  |  |
| date $\triangleq$ (year, month, day : $\mathbb{N}$ ) – injective constructor                                     |  |
| <b>require</b> valid_date(year, month, day)  |  |
| <b>const</b> year, month, day $\in$ DATE $\rightarrow \mathbb{N}$  |  |
| <b>axiom</b> $\forall d \in \text{DATE} \bullet d = \text{date}(\text{year}(d), \text{month}(d), \text{day}(d))$ |  |
| <b>query</b> valid_date(y,m, d: $\mathbb{N}$ ) : $\mathbb{B}$  |  |
| $\triangleq$ <<Table below>>   |  |
| <b>query</b> leap_year(y : $\mathbb{N}$ ) : $\mathbb{B}$   |  |
| $\triangleq$ $\text{mod}(y, 4) = 0 \wedge \text{mod}(y, 400) \notin \{100, 200, 300\}$                           |  |
| <b>require</b> $y \geq 1583$   |  |

Below: *ly* abbreviates *leap\_year*

|  |                                    |                          |               | <i>valid_date</i> |
|--|------------------------------------|--------------------------|---------------|-------------------|
| (1583 ≤ <i>y</i> ≤ 9999)<br>∧(1 ≤ <i>m</i> ≤ 12)<br>∧(1 ≤ <i>d</i> ≤ 31) | <i>m</i> ∈ {1, 3, 5, 7, 8, 10, 12} |                          | true          |                   |
|  | <i>m</i> ∈ {4, 6, 9, 11}           | <i>d</i> ≤ 30            |               | true              |
|  |                                    | <i>d</i> > 30            |               | false             |
|  | <i>m</i> = 2                       | <i>ly</i> ( <i>y</i> )   | <i>d</i> ≤ 29 | true              |
|  |                                    |                          | <i>d</i> > 29 | false             |
|  |                                    | ¬ <i>ly</i> ( <i>y</i> ) | <i>d</i> ≤ 28 | true              |
|  |                                    |                          | <i>d</i> > 28 | false             |
| not the above  |                                    |                          |               | false             |