高生産性と信頼性におけるアジャイル形式工学手法

(Agile Formal Engineering Method for High Productivity and Reliability)

- Agile-SOFL –

劉少英（Shaoying Liu）

法政大学・情報科学部・コンピュータ科学科

Email: sliu@hosei.ac.jp

HP: http://cis.k.hosei.ac.jp/~sliu/

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Overview

1. Can We “Fall in Love” with Agile Approaches?
2. The SOFL Formal Engineering Method
3. Agile-SOFL: Agile Formal Engineering Method
4. Agile-SOFL Three-Step Specification and Animation
5. Specification-Based Incremental Implementation
6. Testing-Based Formal Verification
7. Tool Support for Agile-SOFL
8. Conclusions and Future Research
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1. Can We "Fall in Love" with Agile Approaches?

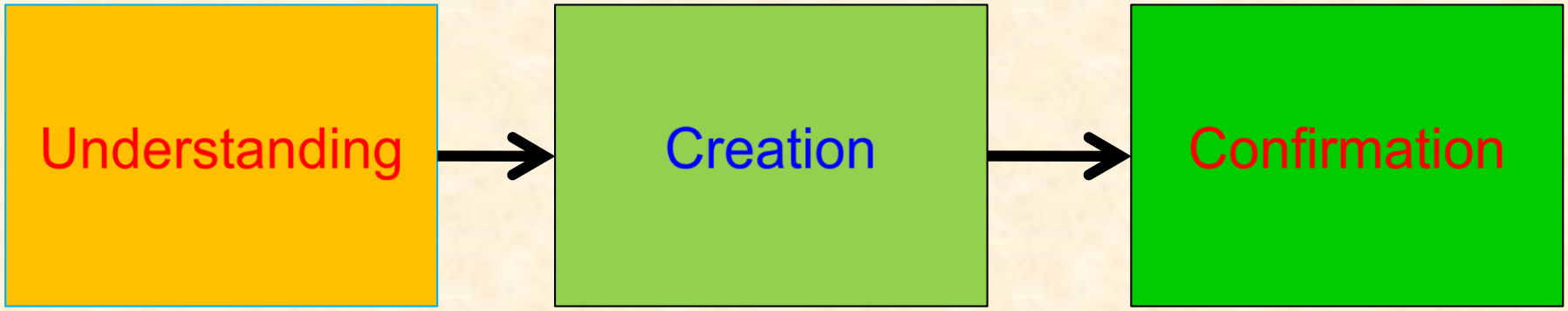
My answer: Yes and No!

Yes: if your project is small and short
(<= 5000 LOC, <= 5 months).

No: if your project is large and long, especially for a critical system.

Why?

Necessary activities for producing highly reliable software systems:



Agile manifesto:

(1) Individuals and interactions over processes and tools

(2) Working software over comprehensive documentation

(3) Customer collaboration over contract negotiation

(4) Responding to change over following a plan

Advantages and Disadvantages of Agile Approaches

Advantages:

- Working software can help strengthen the communication between the developer and the end-user.
- No comprehensive documentation except code can help reduce the time for documentation and the time for configuration management.
- Quick releases can be expected.

Disadvantages:

- Frequent changes of code is inevitable (for lacking sufficient understanding of the requirements in the beginning), which can be extremely difficult and time-consuming.
- Understanding of code is required, which can be extremely hard as well.
- Frequent changes may create more bugs in code and testing to uncover the bugs is time-consuming.

2. The SOFL Formal Engineering Method

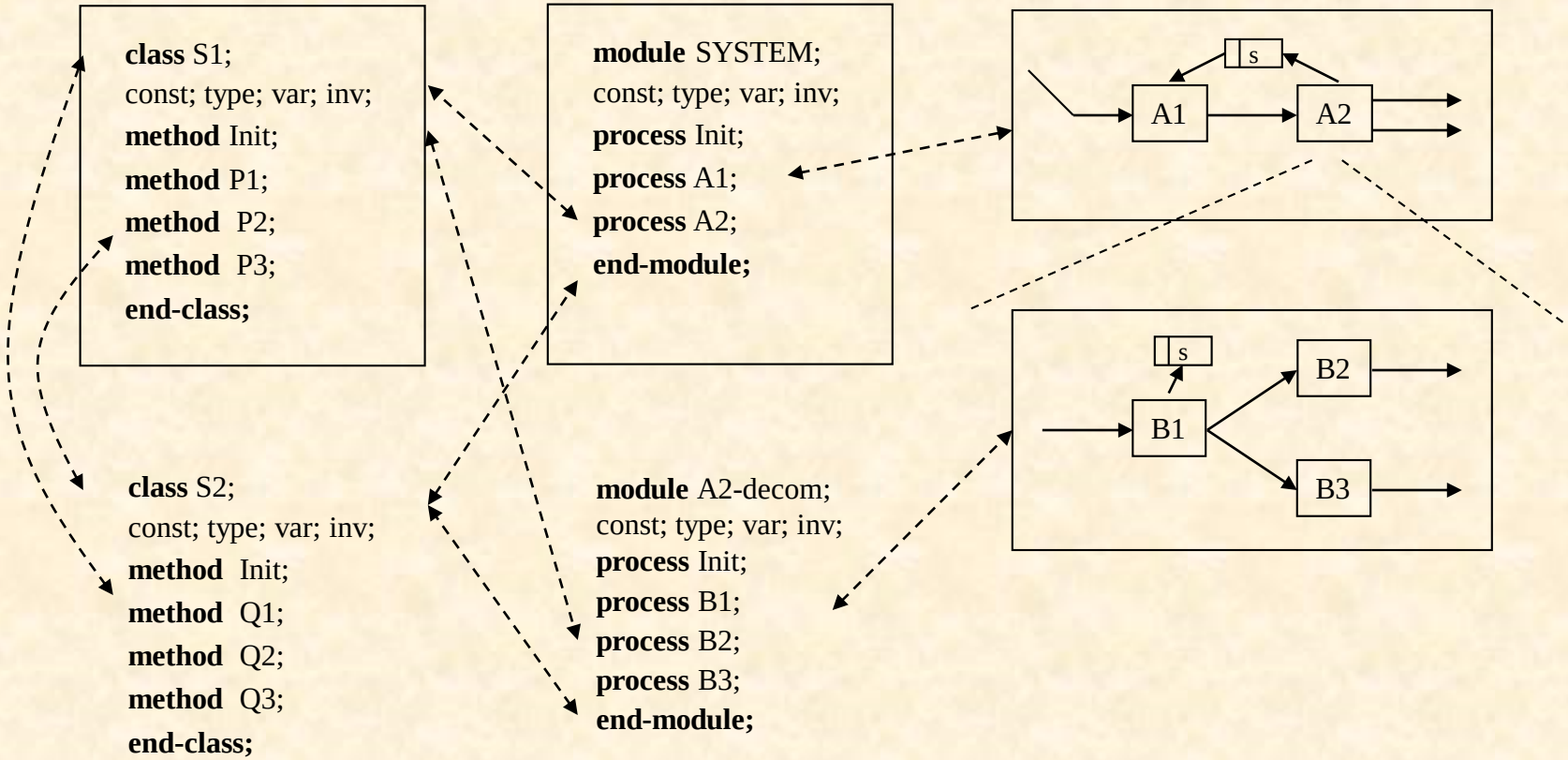
Characteristics:

- Integration of formal methods (FM) with conventional software engineering technologies
- Comprehensible formal specification-based software construction and verification (inspection and testing), more practical than FM
- High automation in inspection and testing

Challenges:

- Time consuming for formal specification construction and evolution to keep consistency with the code.
- Difficult in communication between stakeholders via formal specifications.

The structure of a SOFL specification:
CDFDs + modules + classes



Questions?

(1) Whether the disadvantages of Agile approaches can be overcome by taking advantage of the SOFL formal engineering method?

(2) If yes, how?

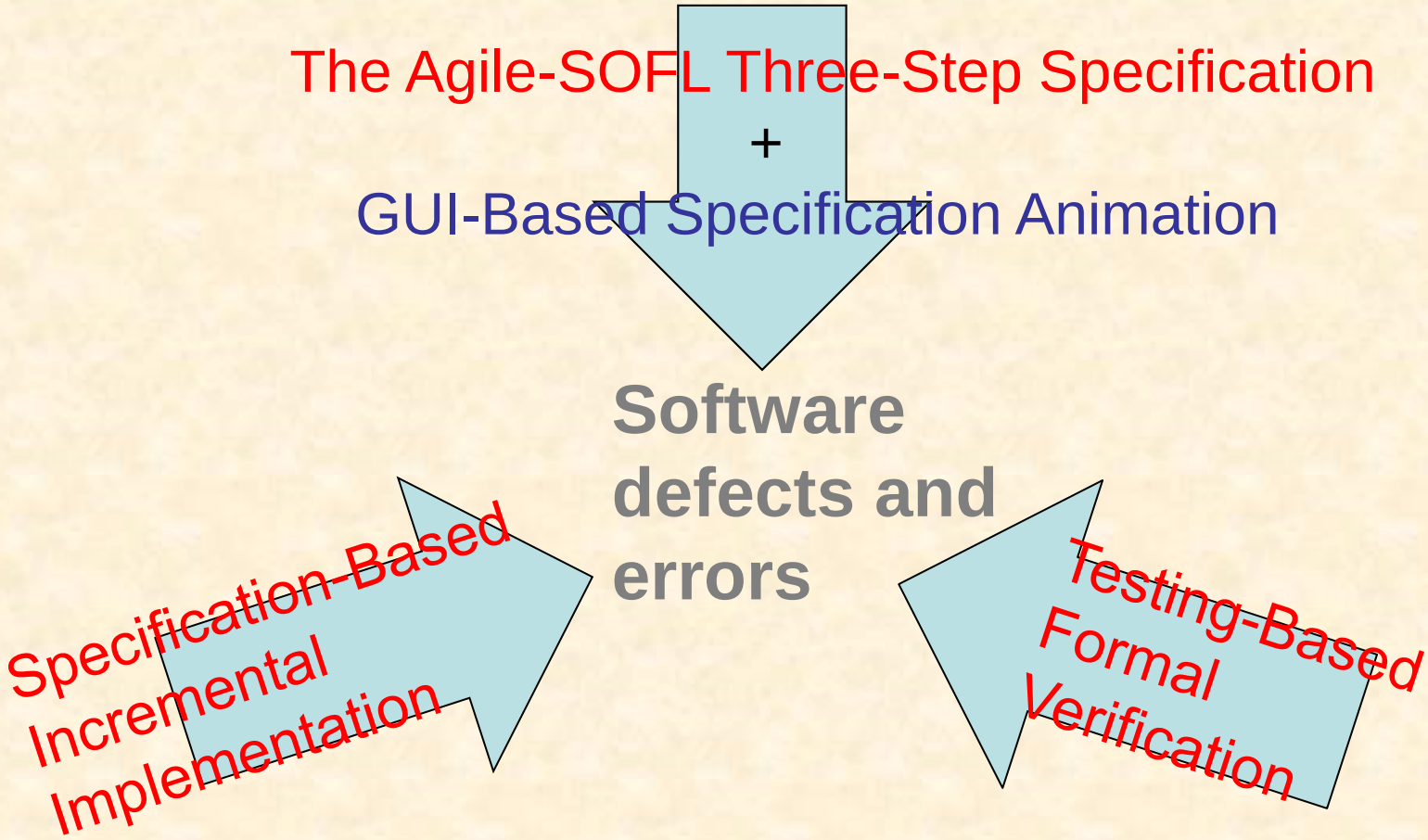
3. Agile-SOFL: Agile Formal Engineering Method

Agile-SOFL is a FEM with effective techniques to achieve the values given in the Agile manifesto.

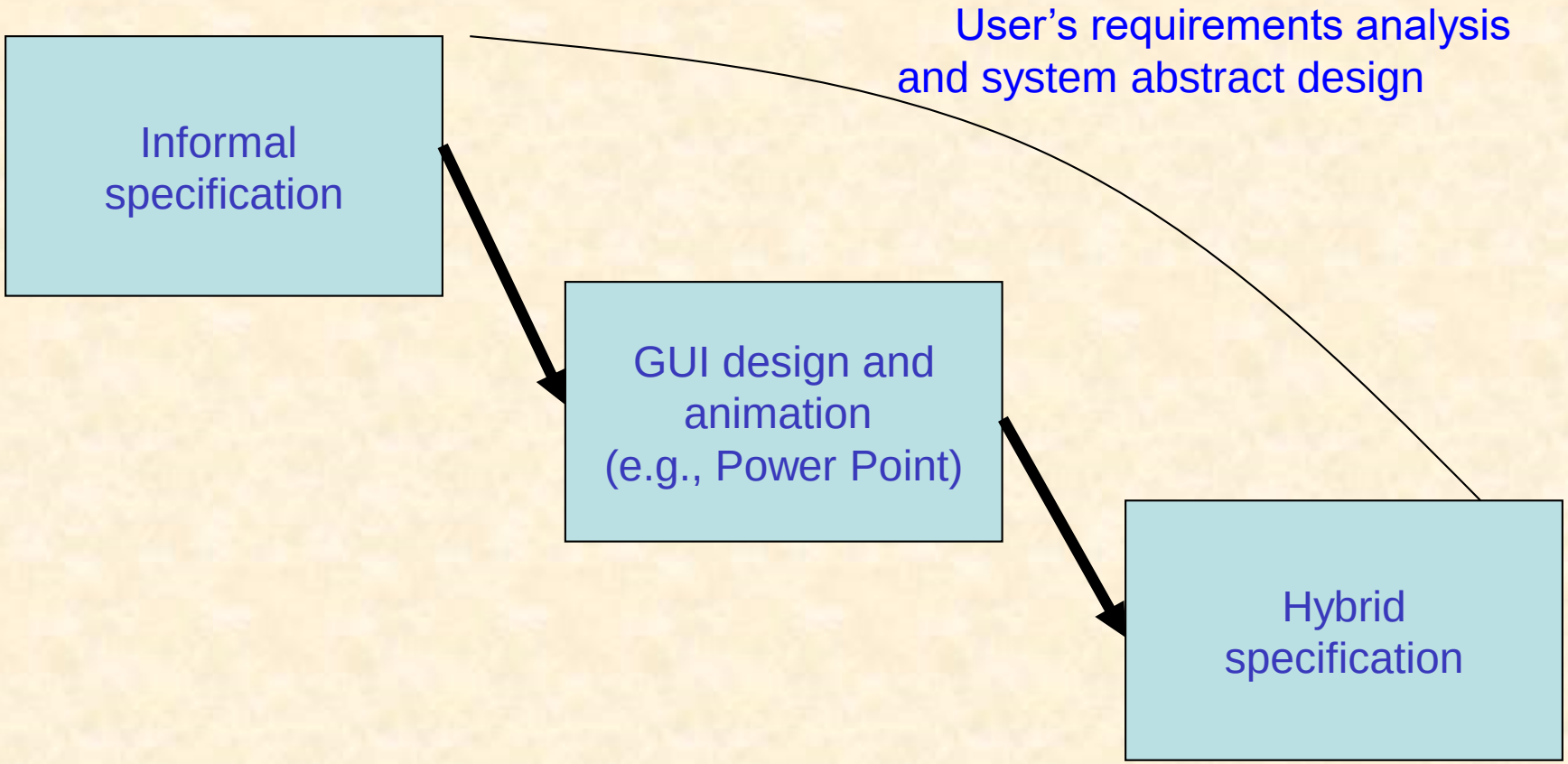
Characteristics:

1. A three-step approach to building comprehensible hybrid specification for analyzing requirements and defining what to be done by the potential system.
2. Animation-based techniques for specification validation.
3. Testing-Based Formal Verification (TBFV) for program verification.
4. Incremental implementation together with the application of TBFV in small cycles

Principle of Agile-SOFL

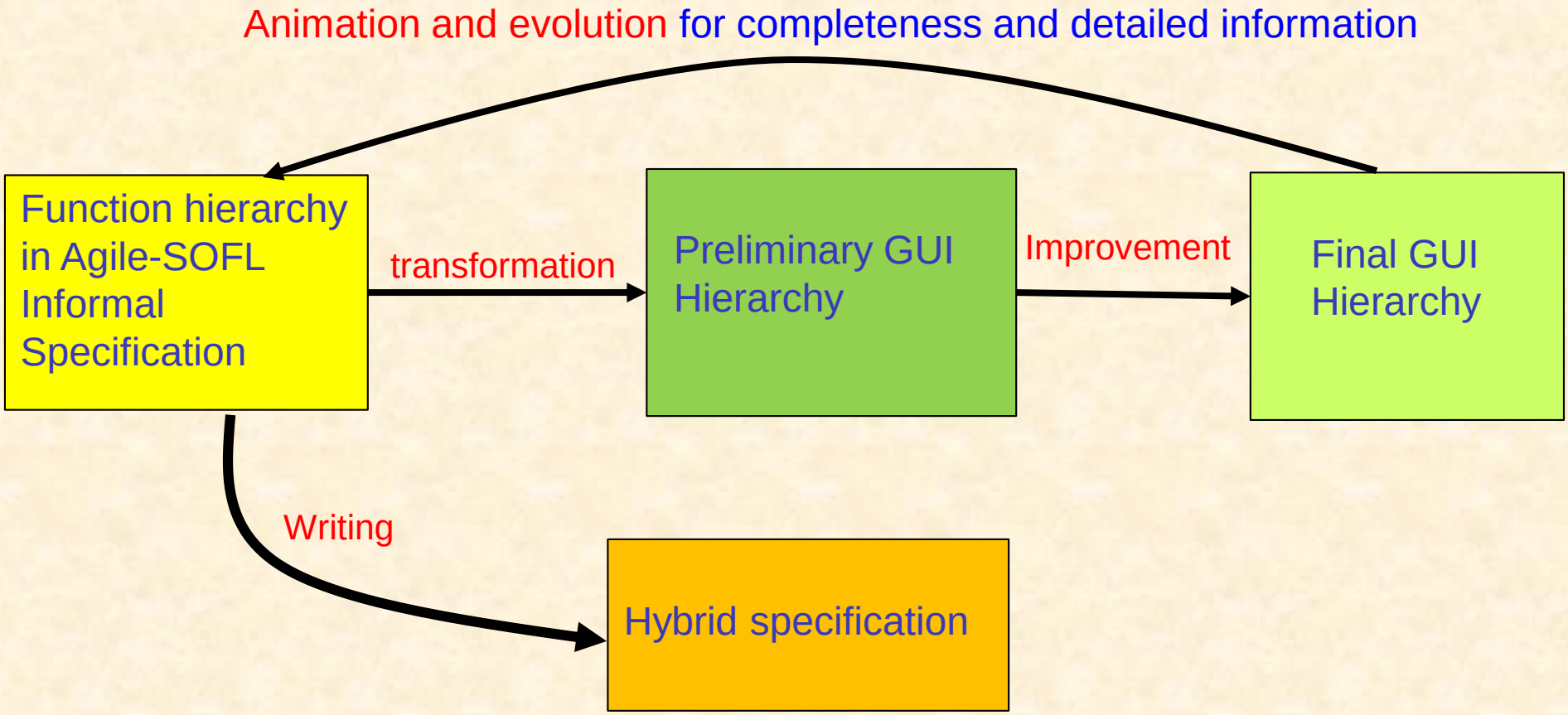


4. Agile-SOFL Three-Step Specification

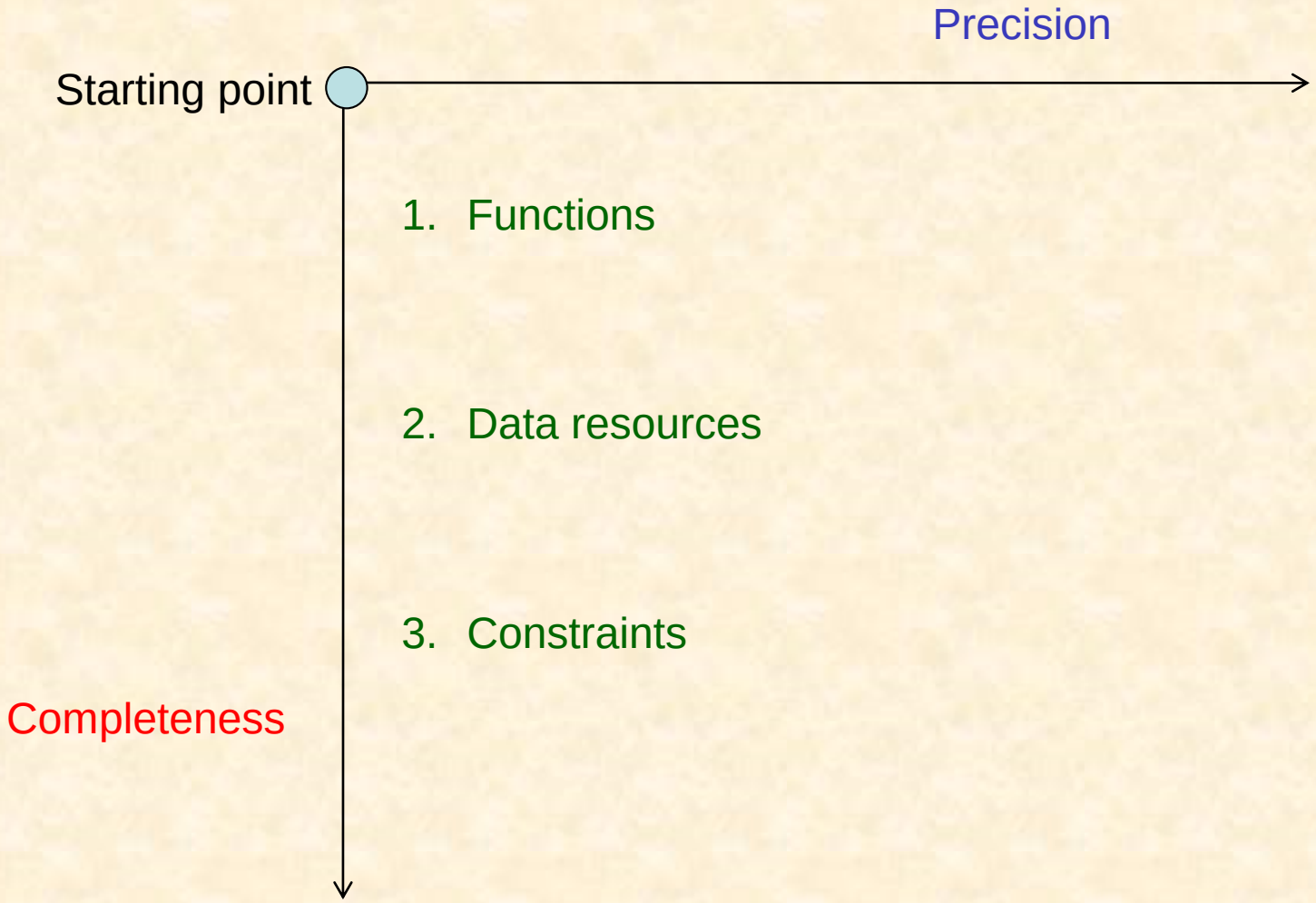


An Agile-SOFL hybrid specification is a specification written in SOFL that contains both semi-formal specifications and formal specifications for operations.

Major Ideas of the GUI-Aided Approach to Writing Hybrid Specifications



Tasks for informal specification: Capturing desired **functions**, necessary **data resources**, and **constraints** on both functions and data resources.



Informal Specification

Informal specification for a simplified ATM software:

1.Functions
- **1.1 Register a customer**
- **1.2 Withdraw from the bank account**
  - **1.2.1 Check the card id and password**
  - **1.2.2 Check the amount for withdrawal**
  - **1.2.3 Update the account balance after withdrawal**
- **1.3 Deposit to the bank account**
- **1.4 Transfer from one bank account to another**
- **1.5 Inquire about the balance of the bank account**
- **1.6 Finish operations**

2. Data resources
- **2.1 Bank account (F1.2, F1.3, F1.4, F1.5)**
  - **2.1.2 Account name**
  - **2.1.2 Account number**
  - **2.1.3 Account password**
  - **2.1.4 Account balance**
  - **2.1.5 Bank name**
  - **2.1.6 Bank branch code**
- **2.2 Accounts file (F1.2, F1.3, F1.4, F1.5) /*containing a set of bank accounts*/**
- **2.3 Customer information(F1.1)**

3. Constraints
- **3.1 Each withdrawal from a bank account must not exceed 200,000 JPY.**
- **3.2 The account balance cannot be less than 0.**
- **3.3 The amount of each transfer cannot exceed 1,000,000 JPY.**
- **3.4 The amount of each deposit cannot exceed 500,000 JPY**

Tasks for GUI design and animation:

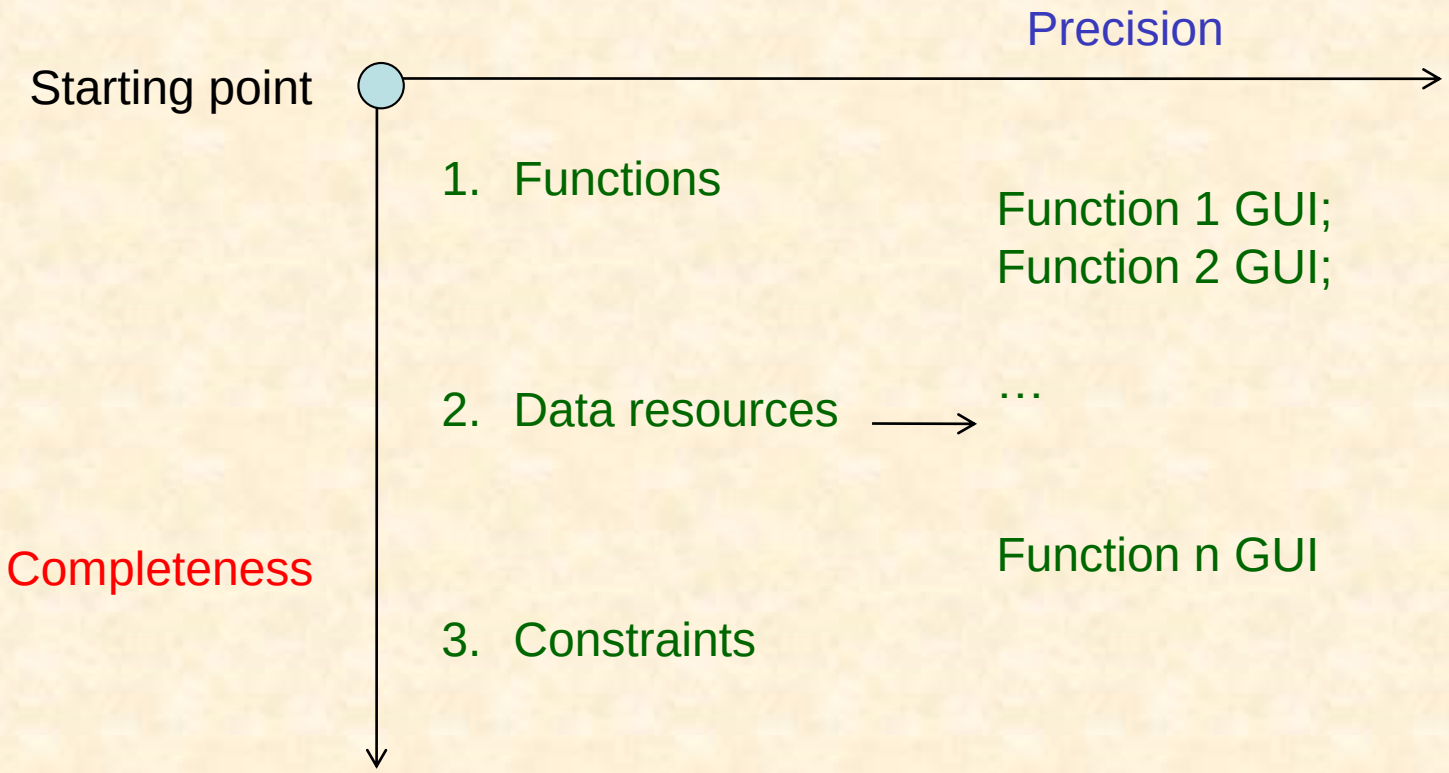
(1) Select the functions from the informal specification that need interactions with the user of the system

(2) Design the GUI (e.g., with Power Point) for each function to clearly show what input and output are necessary

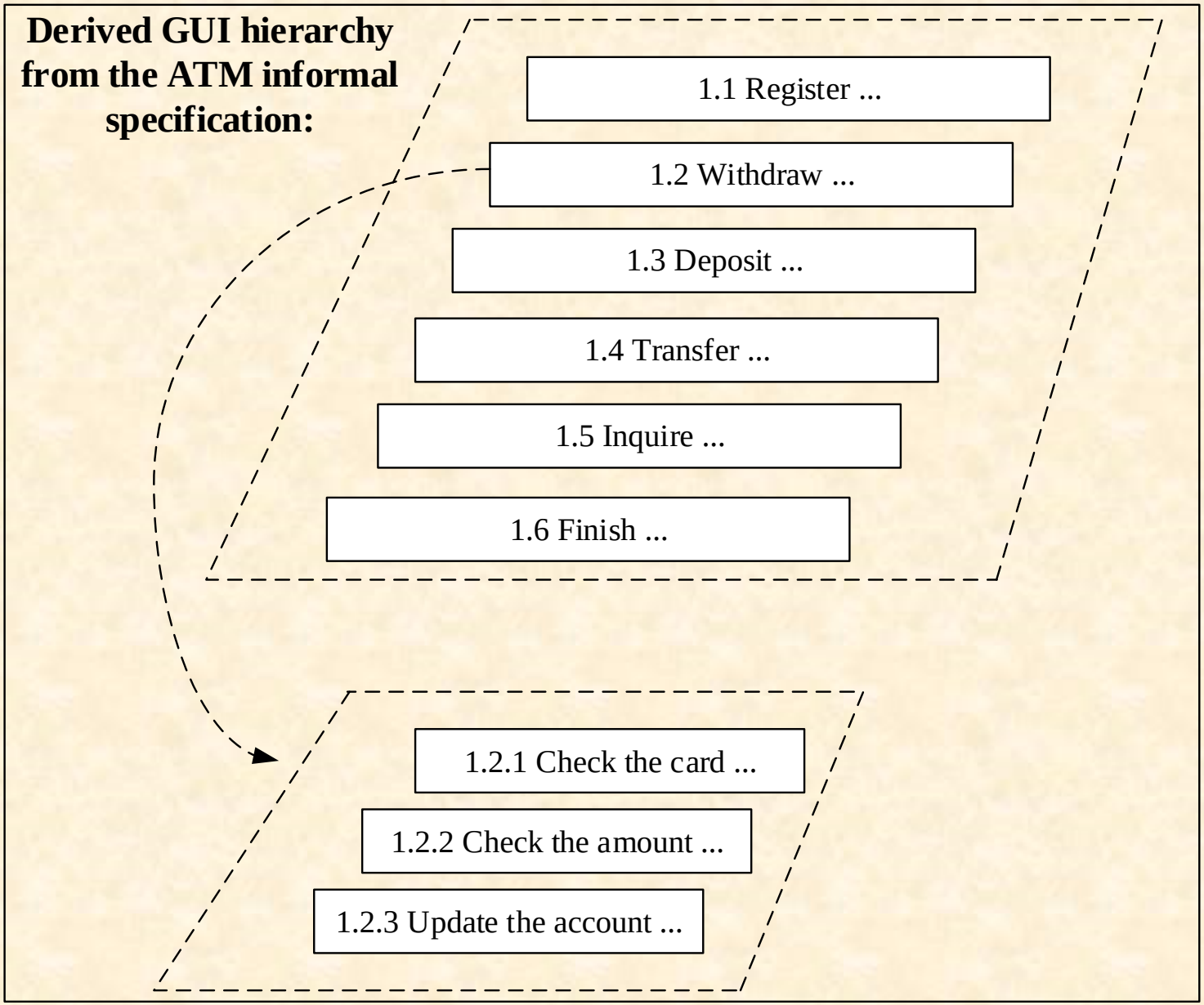
(3) Perform GUI animation (e.g., using Power Point) to demonstrate what input can be used to produce what output.

(4) Improve the expression of the corresponding functions in the informal specification using PRN (Production Rule Notation)

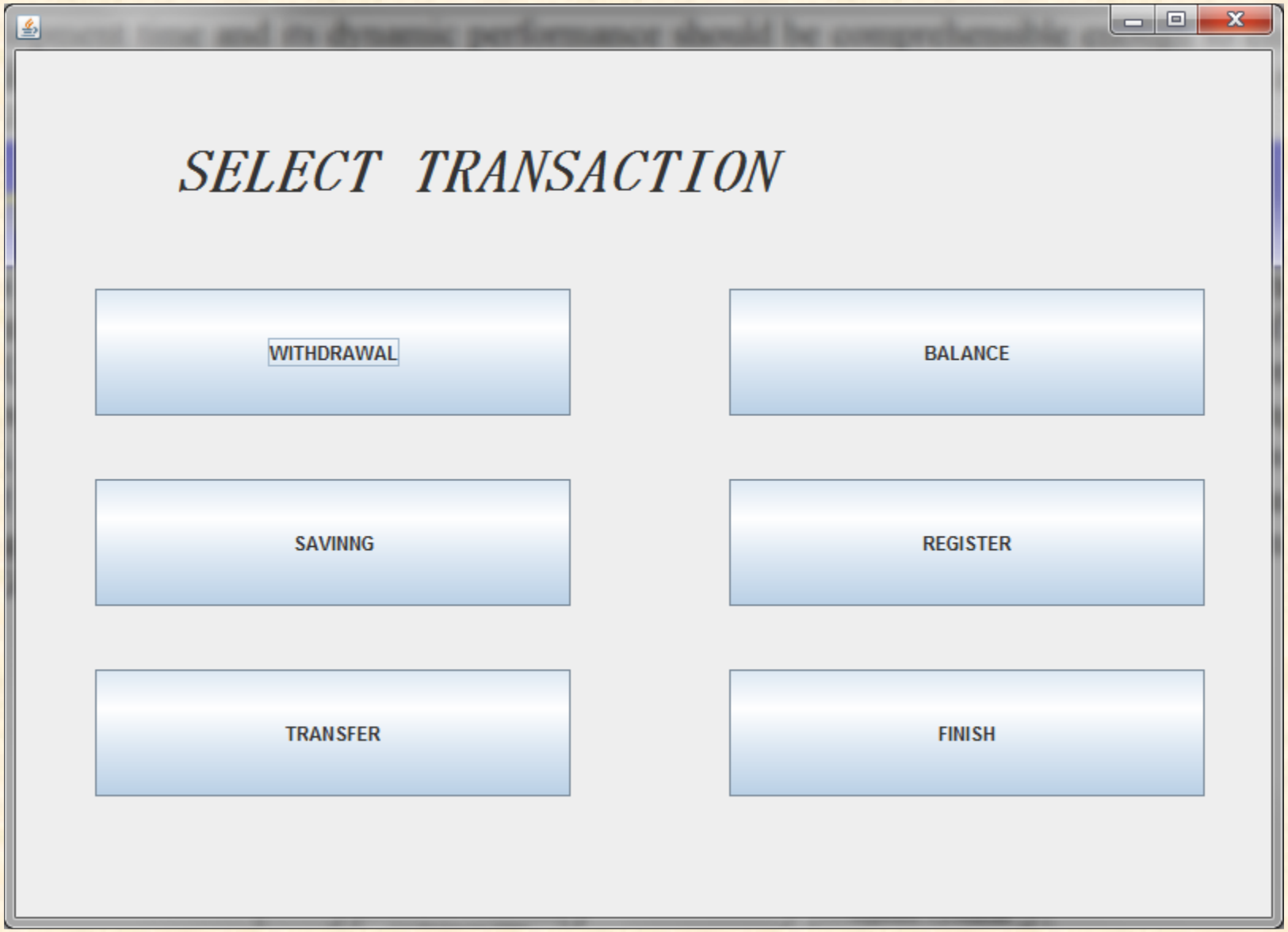
The result of the GUI design and animation phase:



Example


Derived GUI hierarchy from the ATM informal specification:
1.1 Register ...
1.2 Withdraw ...
1.3 Deposit ...
1.4 Transfer ...
1.5 Inquire ...
1.6 Finish ...
1.2.1 Check the card ...
1.2.2 Check the amount ...
1.2.3 Update the account ...

Improved Final GUI



Tasks for hybrid specification:

(1) Group the related functions, data items, and constraints given in the informal specification into SOFL modules.

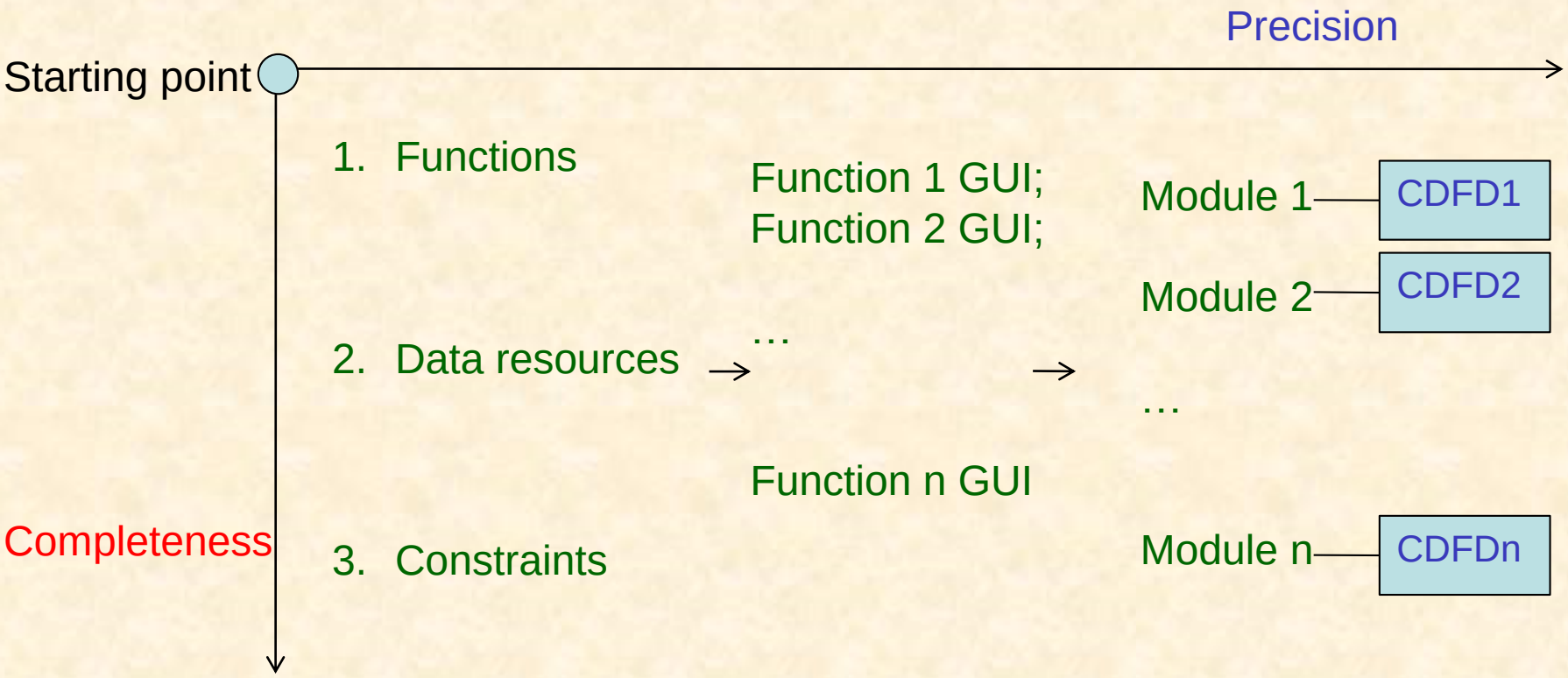
(2) Define necessary types, constants, and declare external variables using well-defined types to precisely represent all of the data items in the informal specification.

(3) Define necessary invariants to precisely represent the constraints given in the informal specification using the SOFL formal notation.

(4) Form processes for each function given in the informal specification and define their data flow dependence using CDFD (condition data flow diagram).

(5) Write specification for each process occurring in the CDFD. Each specification is given in pre- and post-conditions, which can either be a restricted informal expression or a formal expression.

The result of writing the hybrid specification:

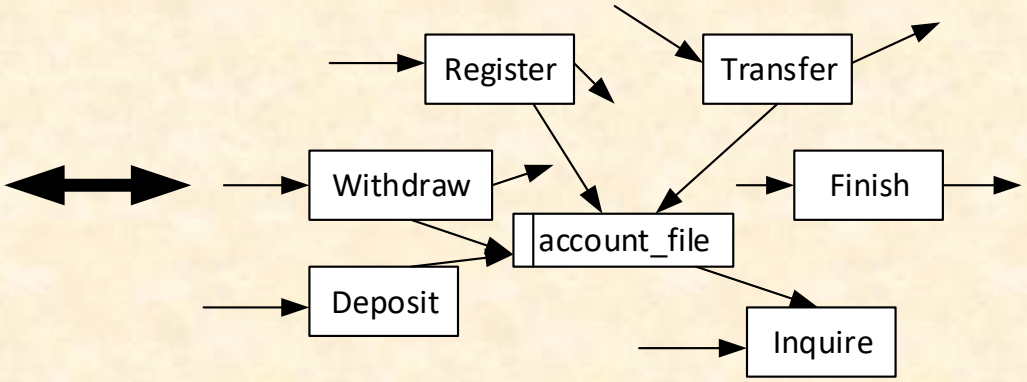


Example

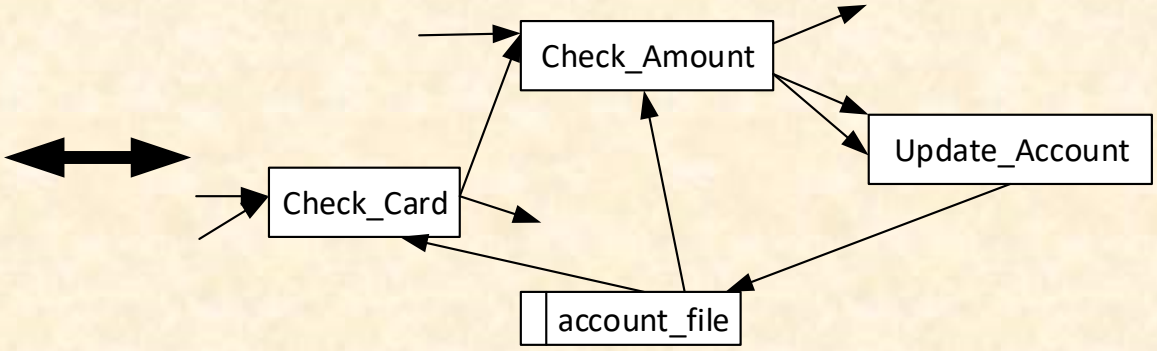
Formal specification:

```
module SYSTEM_ATM;
 data items declarations;
  process Register
  process Withdraw
  process Deposit
  process Transfer
  process Inquire
  process Finish
end_module;
```

No. 1




```
module Withdraw_Decom /
            SYSTEM_ATM;
 data items declarations;
  process Check_Card
  process Check_Amount
  process Update_Account
end_module;
```



No. 2

Details of the specification (example):

```
module SYSTEM_ATM
    type
    Account = composed of
                    account_no: nat
                    password: nat
                    balance: real
                   end
 var
    account_file: set of Account;
 inv
     forall[x: account_file] | x.balance >= 0;
/*Account balance must be greater than or equal to zero. */

...
behav CDFD_No.1;
```

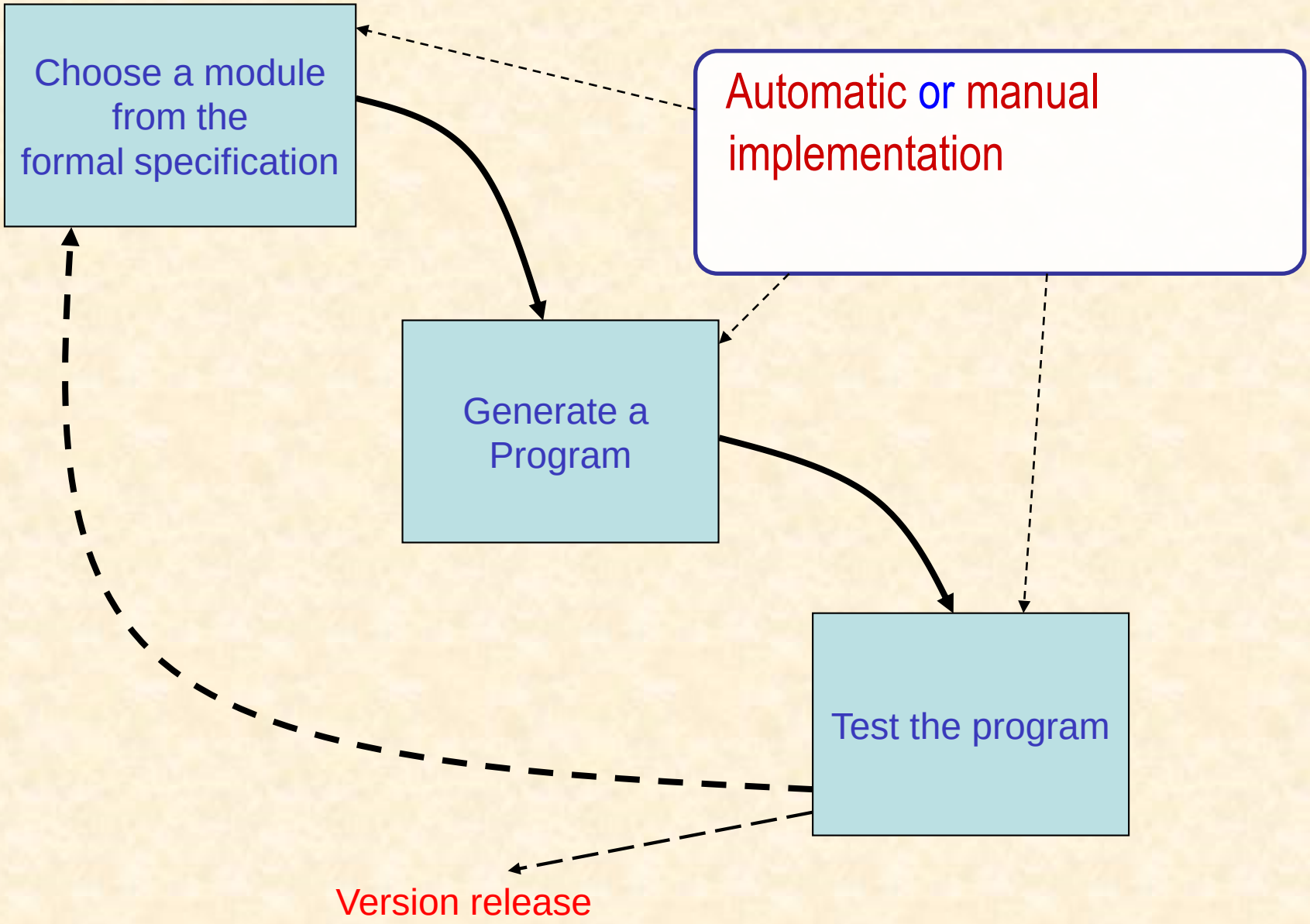
```
process Withdraw(amount: real, account1: Account)
                                e_msg: string | cash: real
 ext wr account_file
 pre account1 is a member of account_file
 post if amount is less than the balance of account1
        then supply cash with the same amount as amount, and
                reduce the amount from the balance of the account.
        else output an appropriate error message e_msg.
end_process;
```

/*Semi-formal specification*/

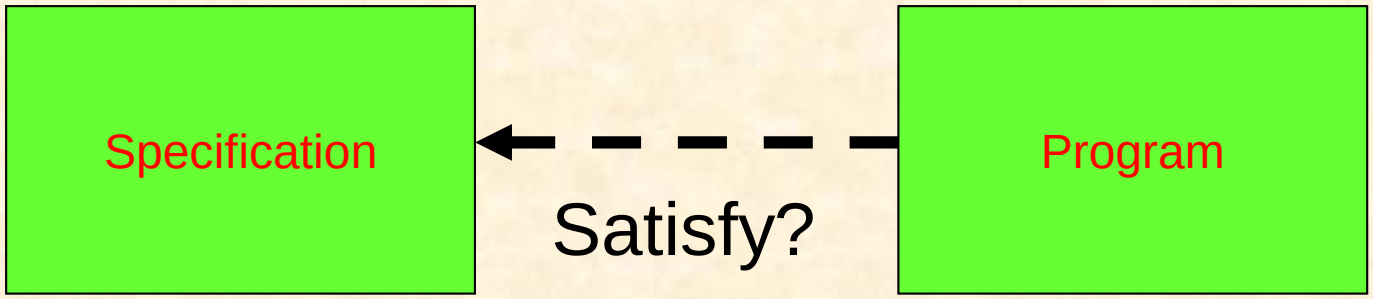
```
process Withdraw(amount: real, account1: Account)
                        e_msg: string | cash: real
 ext wr account_file
 pre account1 inset account_file
 post if amount <= account1.balance
        then
          cash = amount and
          let Newacc =
              modify(account1, balance -> account1.balance – amount)
           in
            account_file = union(diff(~account_file, {account1}), {Newacc})
       else
         e_meg = "The amount is over the limit. Reenter your amount.")
comment
…
end_process;

/*Formal specification*/

end_module
```

5. Specification-Based Incremental Implementation

We take the bottom-up approach to automatically or manually (with tool support) implement and test the system based on the formal specification in an incremental fashion.


Choose a module from the formal specification
Automatic or manual implementation
Generate a Program
Test the program
Version release

6. Testing-Based Formal Verification



using TBFV

The goal:

Dynamically check whether the functions defined in the specification are ``correctly'' implemented by the program

The theoretical foundation for TBFV

A program **P** correctly implements a specification **S** iff

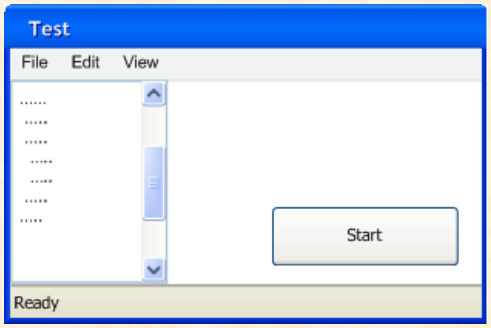
$$S_{pre}(\sim\sigma) \vdash S_{post}(\sim\sigma, P(\sim\sigma))$$

where **~σ** is any initial state and **P(~σ)** is treated as a mathematical function whose definition may not be represented by a mathematical expression but can be represented by an **algorithm.** Therefore, existing formal proof techniques may not be applied for formal Verification of P.

Goal of Automatic TBFV

Automatic test data generation

Press a Button



	x	y	z
case1	3	5	2
case2	0	4	9
case3	9	3	35
.....			
.....			

```
Method(int x, int y, int z){
int w;
if(x < y)
{
  w = y/x;
  while(w < z)
  {
    ...
  }
} else
  ...
}
}
```

Next

Steps of TBFV:

(1) Generate test data from the specification.

(2) Execute the program using the test data.

(3) Analyze test results to detect bugs based on the test data, the result of execution, and the specification.

General criteria for test data generation and for test result analysis:

Definition 5.1 (FSF)

Let $S_{post} \equiv G_1 \wedge D_1 \vee G_2 \wedge D_2 \vee \cdots \vee G_n \wedge D_n$,

G_i: guard condition

D_i: defining condition.

$i = 1,\ldots,n$.

Then, a functional scenario form (FSF) of S is:

$(S_{pre} \wedge G_1 \wedge D_1) \vee (S_{pre} \wedge G_2 \wedge D_2) \vee \cdots \vee (S_{pre} \wedge G_n \wedge D_n)$

Criterion 5.1: Let the FSF of specification S be:

$(S_{pre} \wedge G_1 \wedge D_1) \vee (S_{pre} \wedge G_2 \wedge D_2) \vee \cdots \vee (S_{pre} \wedge G_n \wedge D_n)$

Then, a test set T must be generated to meet the following condition:

$$(\forall G_i \; \exists t \in T \cdot S_{pre} \wedge G_i(t)) \wedge (\exists t \in T \cdot \neg S_{pre})$$

where i = 1,…,n

A criterion for test result analysis:

Criterion 5.2: If the condition

$$\exists\, t \in T \cdot S_{pre}(t) \wedge \neg\, S_{post}(t, P(t))$$

holds, it indicates the existence of bugs in program P.

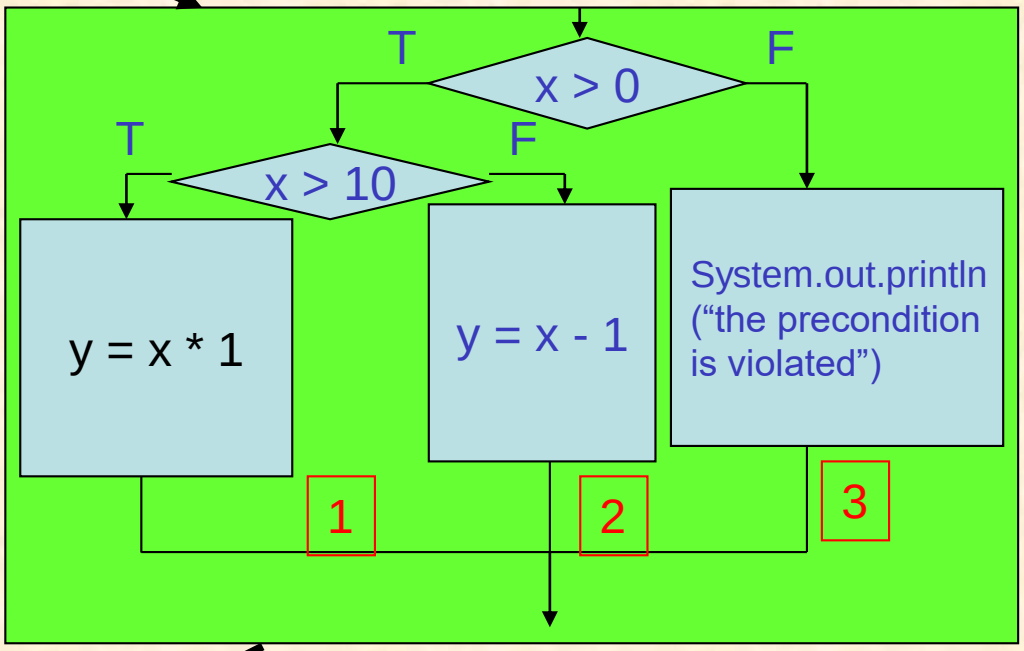
Test case generation

Specification

A(x: int) y: int
pre x > 0
post x > 10 ∧ y = x + 1 ∨
x <= 10 ∧ y = x – 1

Functional scenarios:
(1) x > 0 ∧ x > 10 ∧ y = x + 1
(2) x > 0 ∧ x <= 10 ∧ y = x – 1
(3) x > 0 (optional)

Program



Test result analysis

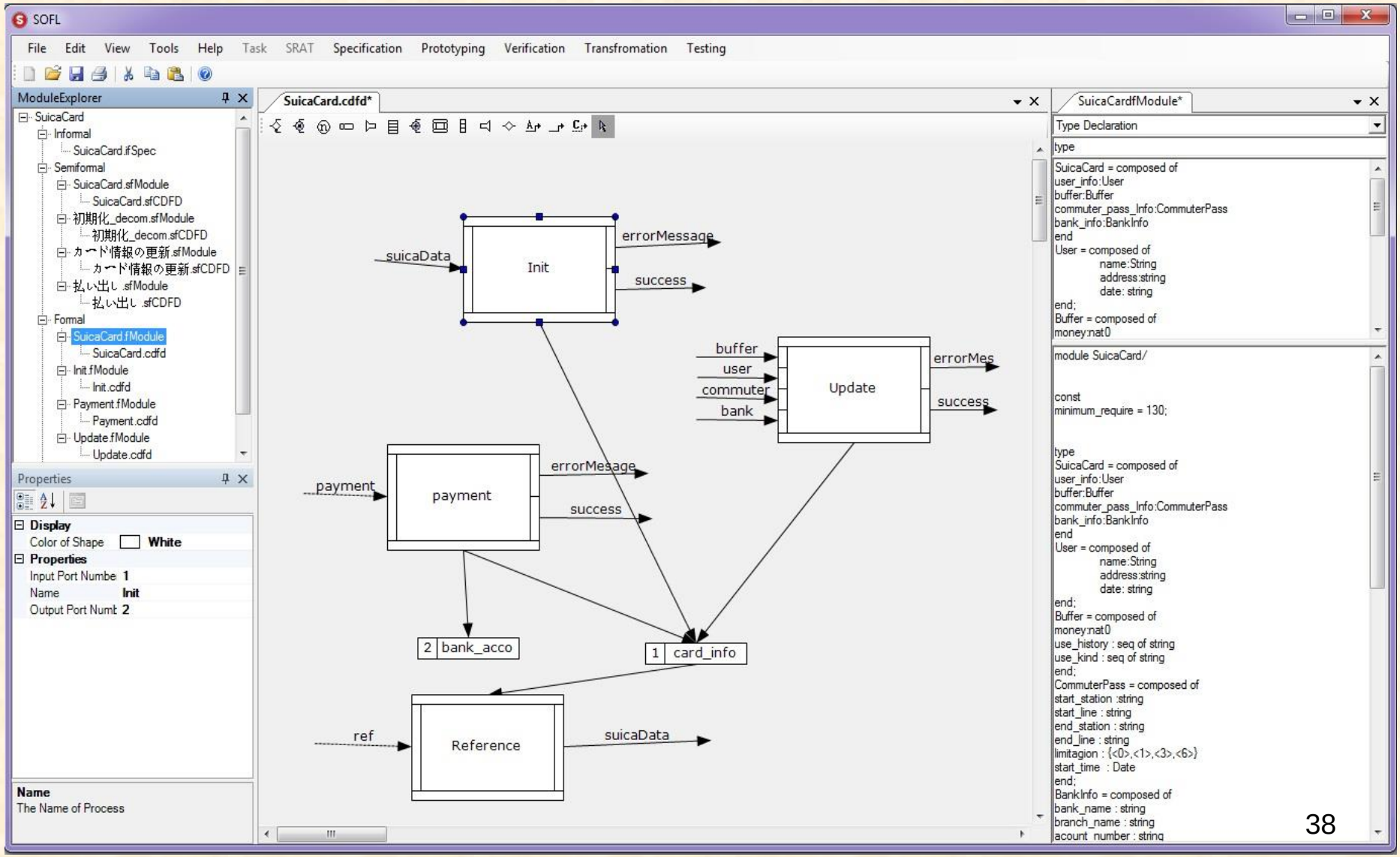
x	y	Apre	Apost	Apre ∧ ¬ Apost
15	15	true	false	true
5	4	true	true	false

7. Tool Support for Agile-SOFL

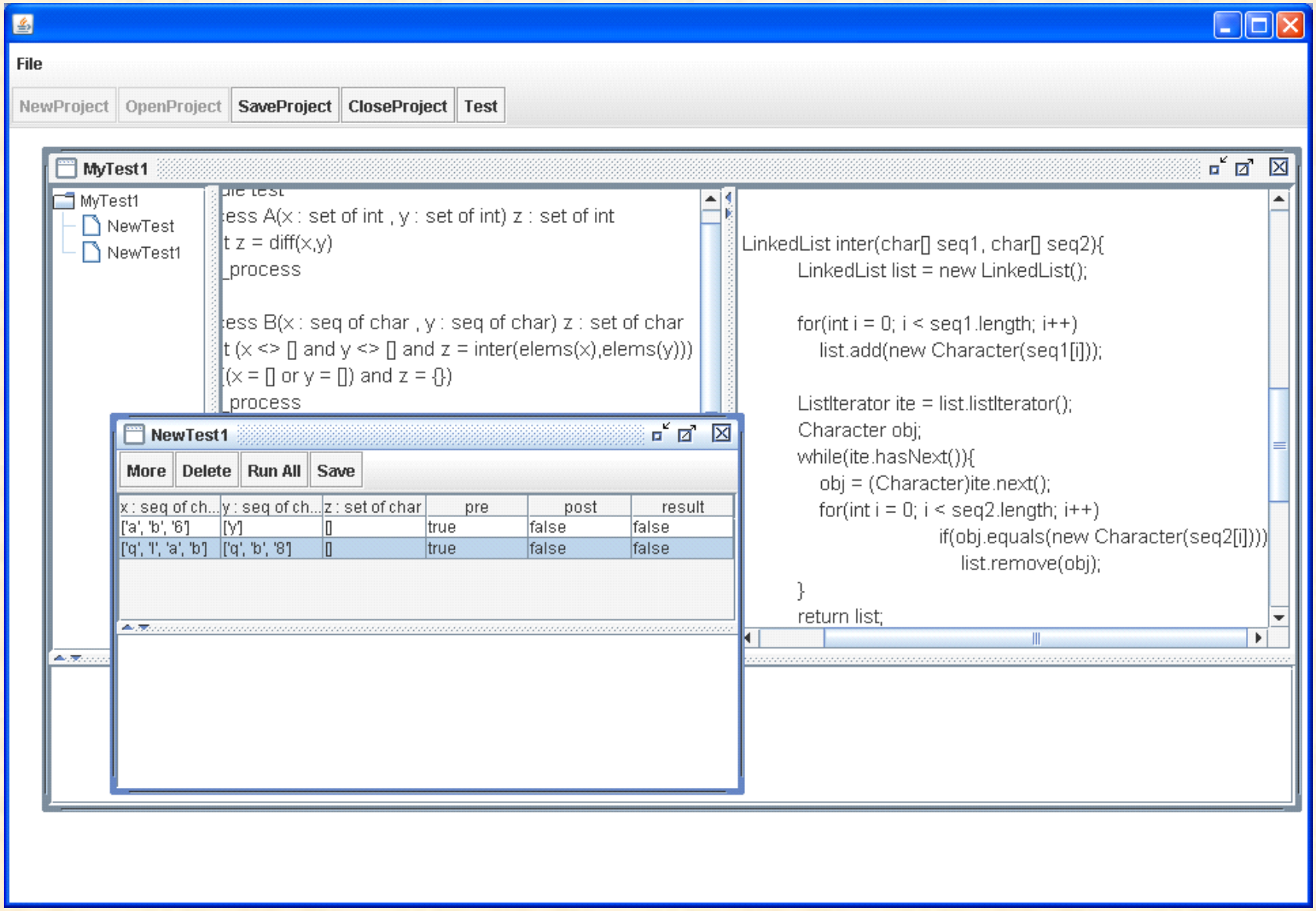
We have several prototype tools to support the SOFL specification language and method.

- Agile-SOFL specification construction tool (SpecTool)
- Tool for Specification-Based Testing

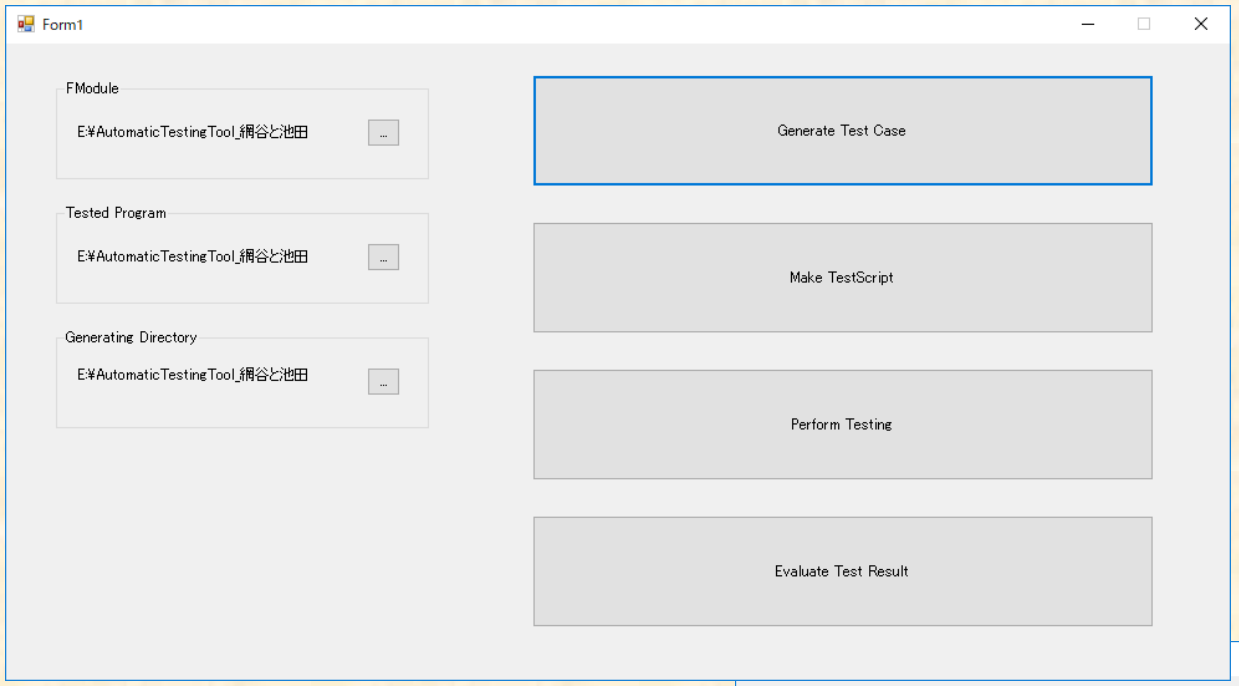
SpecTool for A-SOFL specification

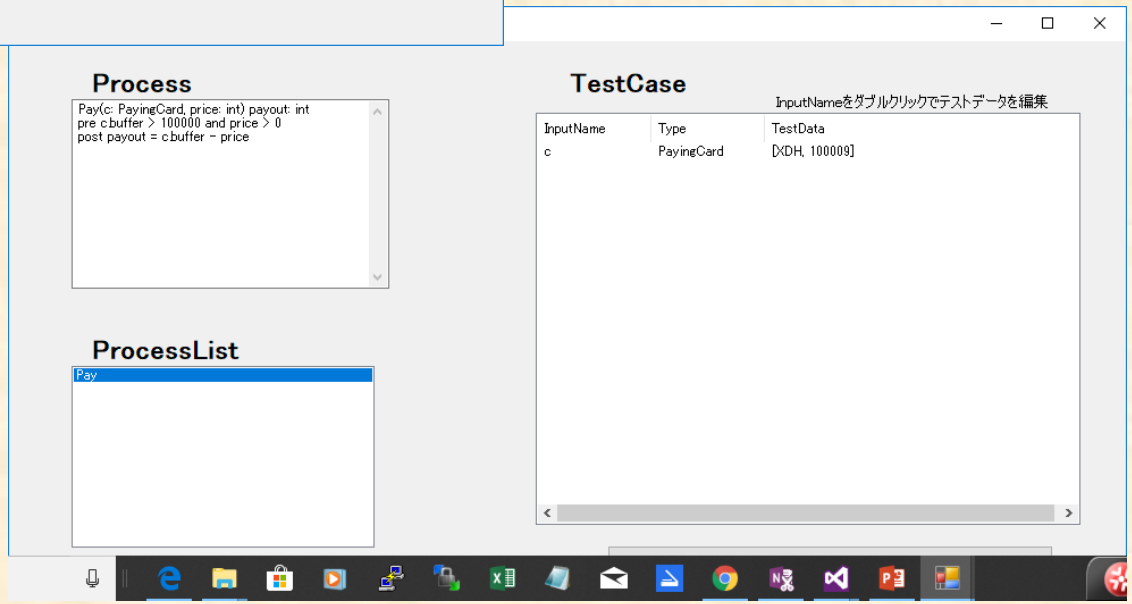


A Tool for TBFV (SBTT)



New Tool for TBFV





10. Conclusions and Future Work

10.1 Conclusions

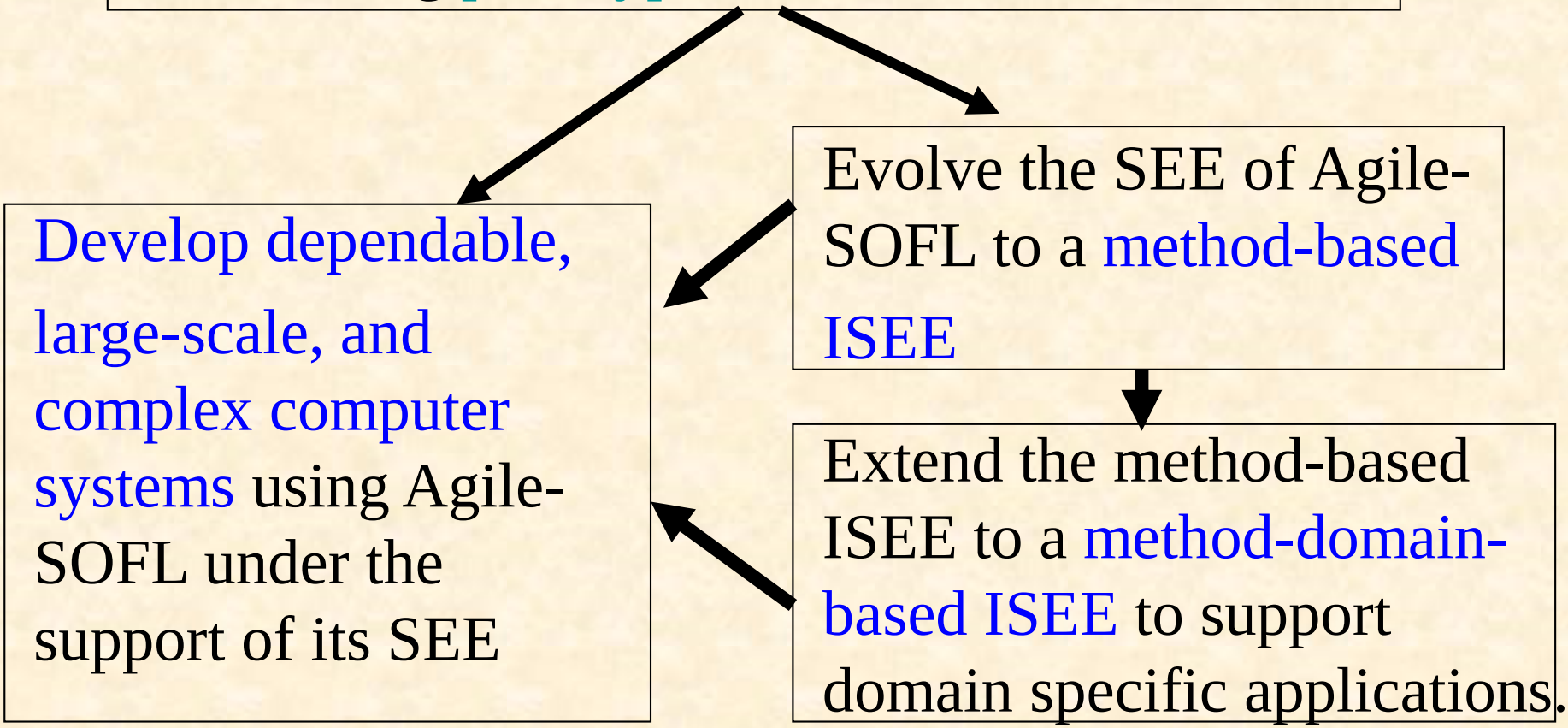
- Agile-SOFL is believed to be much more effective than existing agile approaches for high productivity and reliability, and helpful for system maintenance and extension.

- Agile-SOFL is characterized by the three-step specification approach, specification animation, specification-based incremental implementation, and testing-based formal verification (TBFV) based on SOFL.

- Agile-SOFL supports the values emphasized in the Agile Manifesto, such as **individuals and interactions, working software, customer collaboration, and responding to changes.**

10.2. Future Work

Build a more mature software engineering environment for Agile-SOFL on the basis of the existing prototype tools.



Reference

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(for other publications)