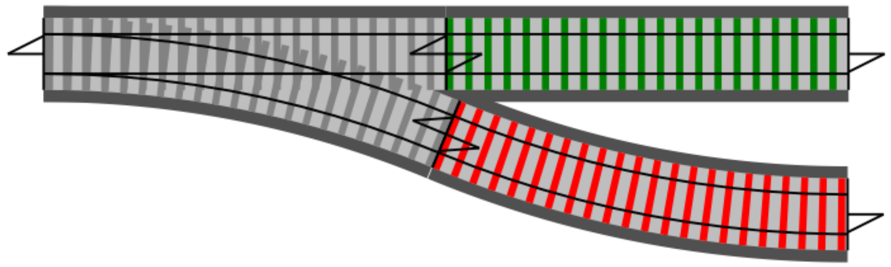
Modelling errors

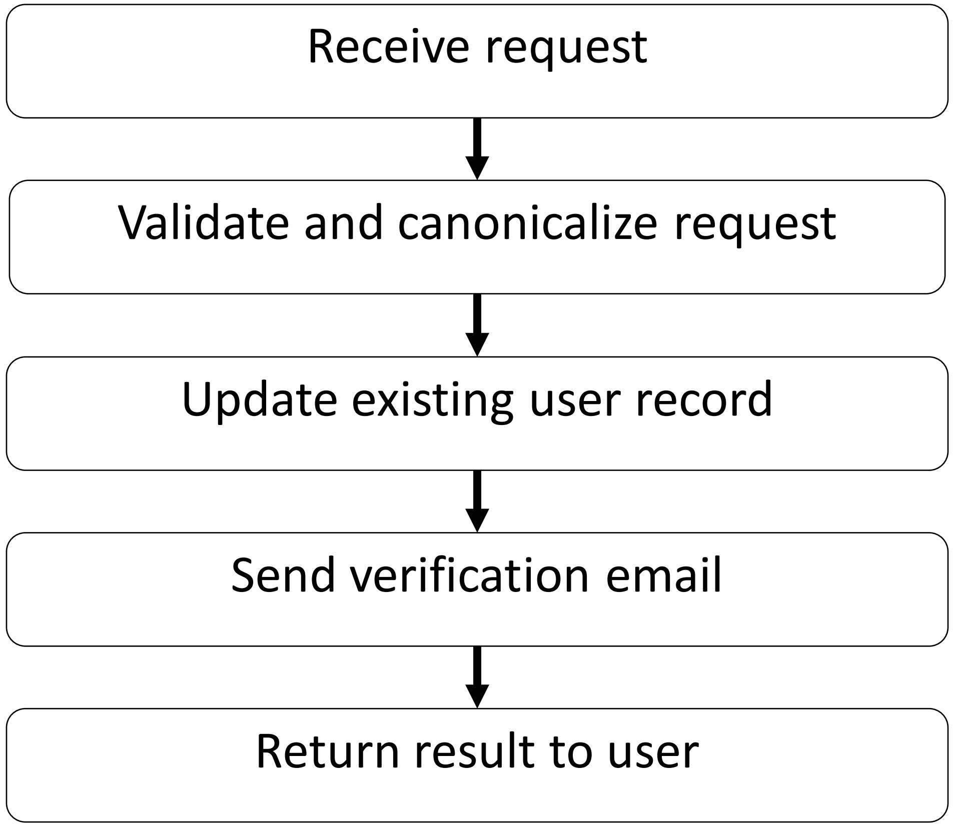


What do railways have to do with programming?

Happy path programming

Implementing a simple use case

"As a user I want to update my name and email address"

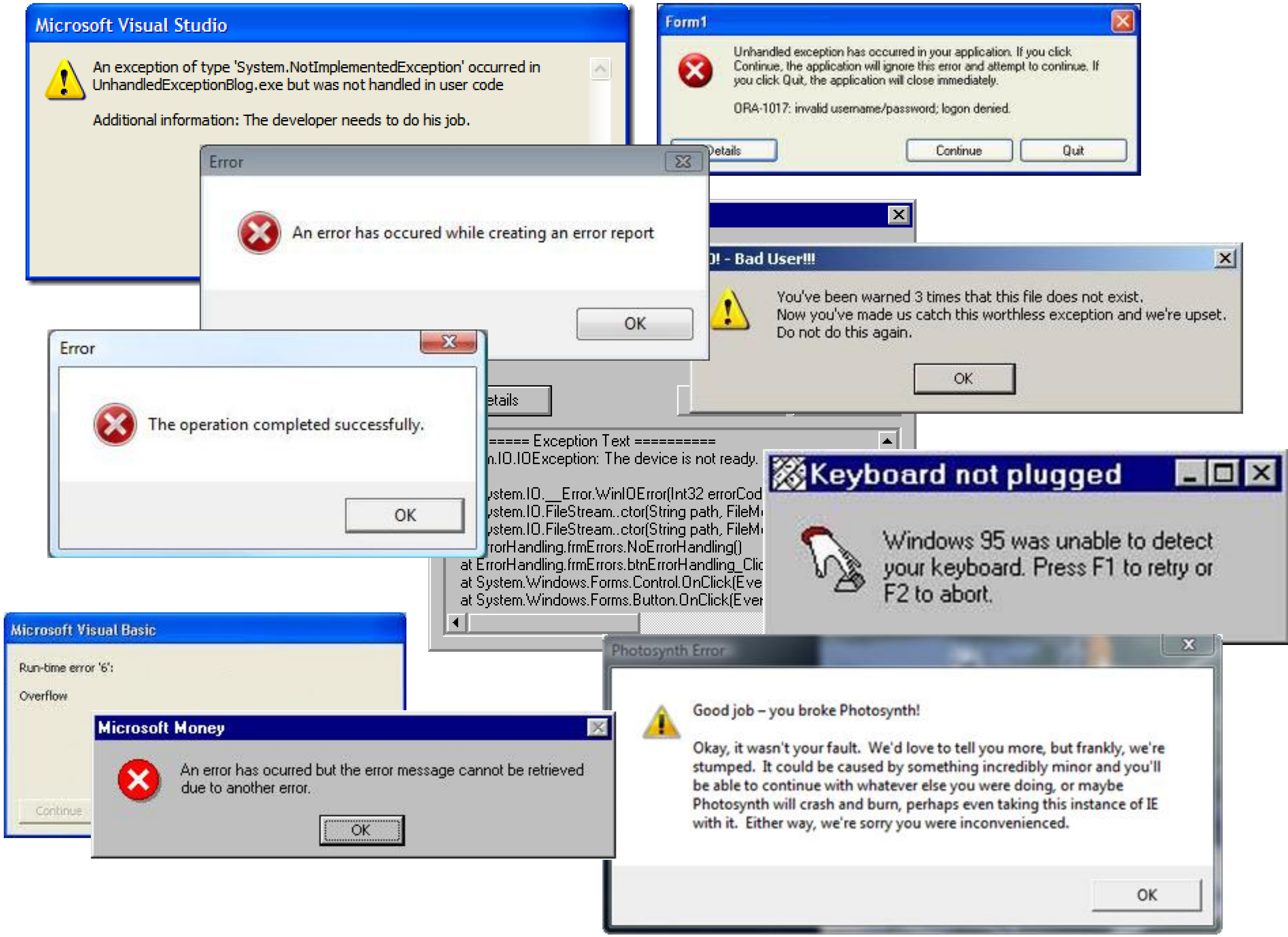

Receive request
Validate and canonicalize request
Update existing user record
Send verification email
Return result to user

```
type Request = {
  userId: int;
  name: string;
  email: string }
```

Straying from the happy path...

What do you do when
something goes wrong?

HAPPY PATH?
WHAT COULD POSSIBLY GO WRONG?



Microsoft Visual Studio

An exception of type 'System.NotImplementedException' occurred in UnhandledExceptionBlog.exe but was not handled in user code

Additional information: The developer needs to do his job.

Form1

Unhandled exception has occured in your application. If you click Continue, the application will ignore this error and attempt to continue. If you click Quit, the application will close immediately.

ORA-1017: invalid username/password; logon denied.

Error

An error has occured while creating an error report

!! - Bad User!!!

You've been warned 3 times that this file does not exist.
Now you've made us catch this worthless exception and we're upset.
Do not do this again.

Error

The operation completed successfully.

```
===== Exception Text ==========
n.IO.IOException: The device is not ready.

ystem.IO.__Error.WinIOError(Int32 errorCod
ystem.IO.FileStream..ctor(String path, FileM
ystem.IO.FileStream..ctor(String path, FileM
rorHandling.frmErrors.NoErrorHandling()
at ErrorHandling.frmErrors.btnErrorHandling_Clic
at System.Windows.Forms.Control.OnClick(Eve
at System.Windows.Forms.Button.OnClick(Ever
```

Keyboard not plugged

Windows 95 was unable to detect your keyboard. Press F1 to retry or F2 to abort.

Microsoft Visual Basic

Run-time error '6':

Overflow

Microsoft Money

An error has ocurred but the error message cannot be retrieved due to another error.

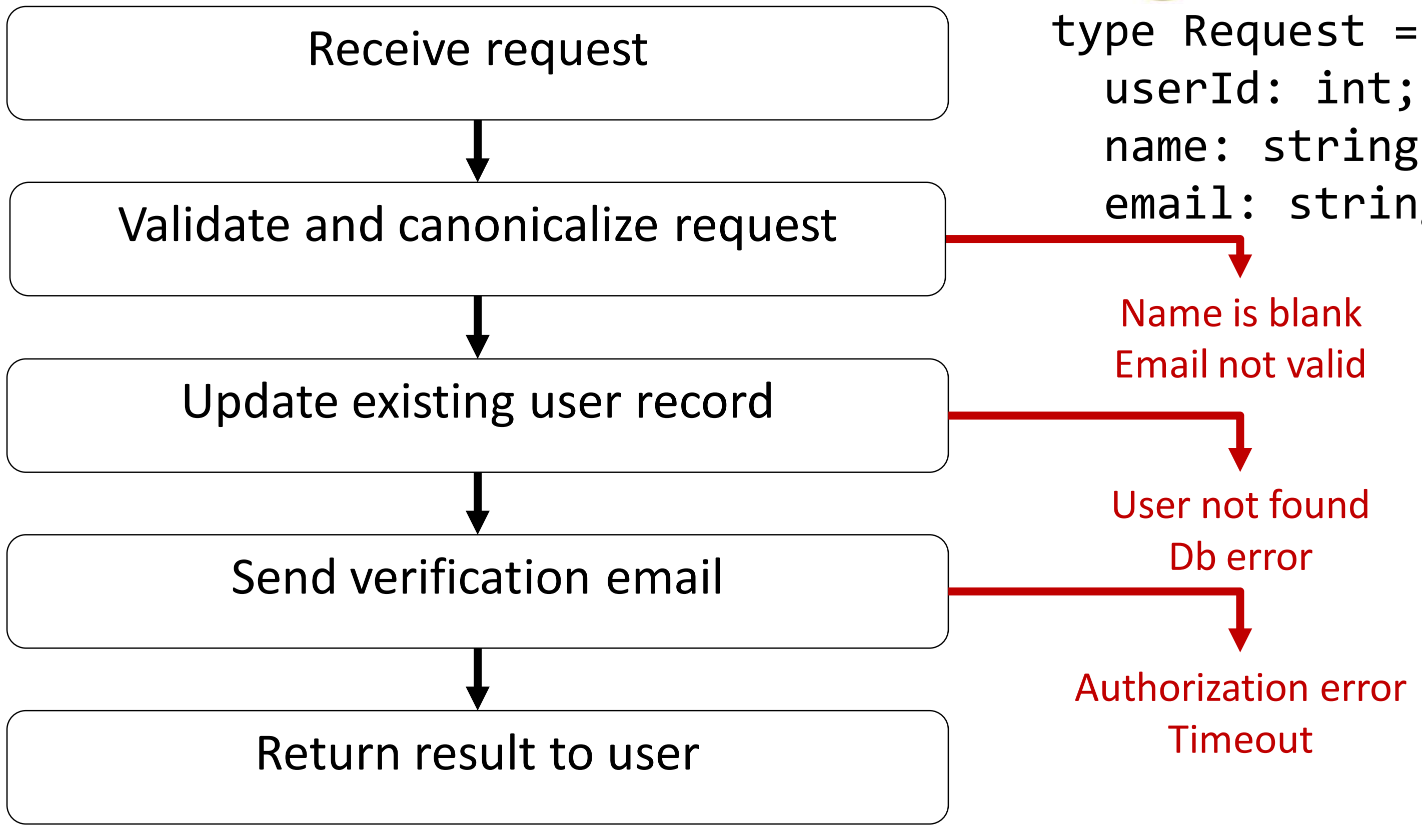
Photosynth Error

Good job – you broke Photosynth!

Okay, it wasn't your fault. We'd love to tell you more, but frankly, we're stumped. It could be caused by something incredibly minor and you'll be able to continue with whatever else you were doing, or maybe Photosynth will crash and burn, perhaps even taking this instance of IE with it. Either way, we're sorry you were inconvenienced.

"As a user I want to update my name and email address"
- and see sensible error messages when something goes wrong!

```
type Request = {
  userId: int;
  name: string;
  email: string }
```



```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  validateRequest(request);
  canonicalizeEmail(request);
  db.updateDbFromRequest(request);
  smtpServer.sendEmail(request.Email)

  return "OK";
}
```

```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  var isValidated = validateRequest(request);
  if (!isValidated) {
     return "Request is not valid"
  }
  canonicalizeEmail(request);
  db.updateDbFromRequest(request);
  smtpServer.sendEmail(request.Email)

  return "OK";
}
```

```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  var isValidated = validateRequest(request);
  if (!isValidated) {
     return "Request is not valid"
  }
  canonicalizeEmail(request);
  var result = db.updateDbFromRequest(request);
  if (!result) {
    return "Customer record not found"
  }

  smtpServer.sendEmail(request.Email)

  return "OK";
}
```

```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  var isValidated = validateRequest(request);
  if (!isValidated) {
     return "Request is not valid"
  }
  canonicalizeEmail(request);
  try {
    var result = db.updateDbFromRequest(request);
    if (!result) {
      return "Customer record not found"
    }
  } catch {
    return "DB error: Customer record not updated"
  }

  smtpServer.sendEmail(request.Email)

  return "OK";
}
```

```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  var isValidated = validateRequest(request);
  if (!isValidated) {
     return "Request is not valid"
  }
  canonicalizeEmail(request);
  try {
    var result = db.updateDbFromRequest(request);
    if (!result) {
      return "Customer record not found"
    }
  } catch {
    return "DB error: Customer record not updated"
  }

  if (!smtpServer.sendEmail(request.Email)) {
    log.Error "Customer email not sent"
  }

  return "OK";
}
```

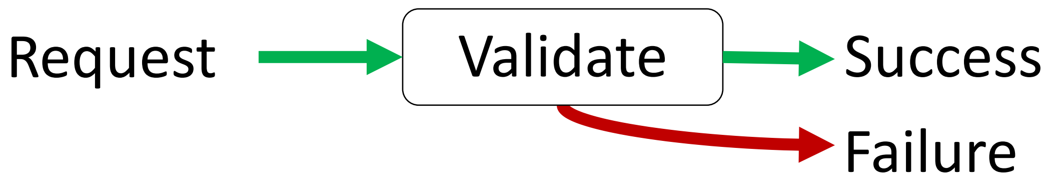
```
string UpdateCustomerWithErrorHandling()
{
  var request = receiveRequest();
  var isValidated = validateRequest(request);
  if (!isValidated) {
     return "Request is not valid"
  }
  canonicalizeEmail(request);
  try {
    var result = db.updateDbFromRequest(request);
    if (!result) {
      return "Customer record not found"
    }
  } catch {
    return "DB error: Customer record not updated"
  }

  if (!smtpServer.sendEmail(request.Email)) {
    log.Error "Customer email not sent"
  }

  return "OK";
}
```

Q: What is the functional equivalent of this code?

... and can we preserve the elegance of the original functional version?

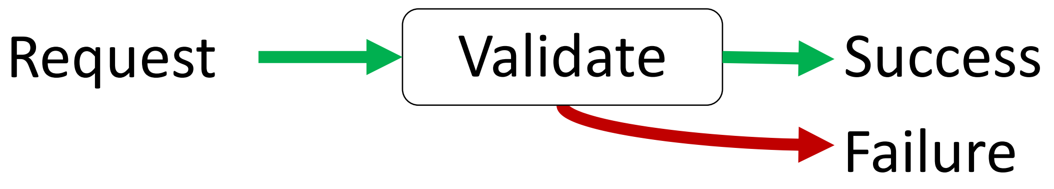
6 clean lines -> 18 ugly lines. 200% extra!
Sadly this is typical of error handling code.

Use a *Result* type for error handling

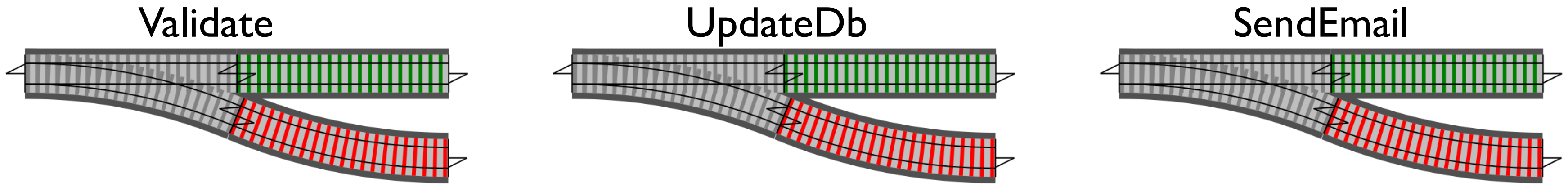


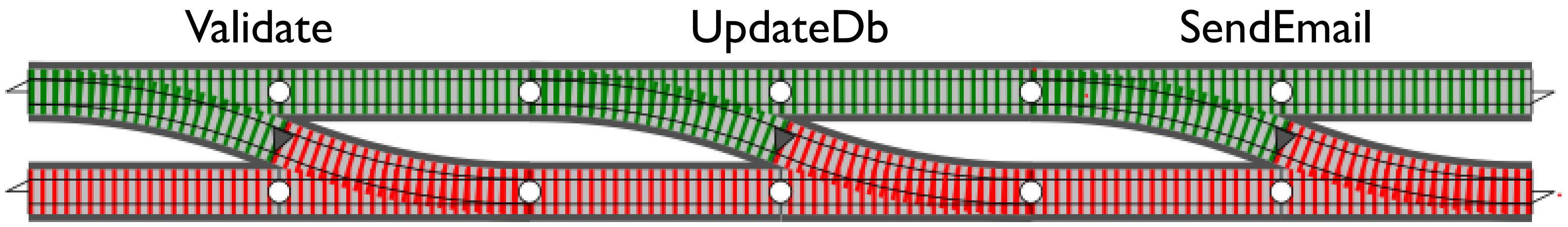
```
type Result =
    | Ok of SuccessValue
    | Error of ErrorValue
```

Define a choice type



```
let validateInput input =
    if input.name = "" then
        Error "Name must not be blank"
    else if input.email = "" then
        Error "Email must not be blank"
    else
        Ok input  // happy path
```


Validate
UpdateDb
SendEmail



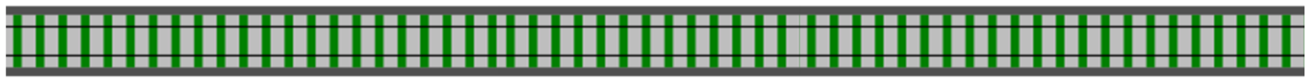
This is the "two track" model –
the basis for the "Railway Oriented Programming"
approach to error handling.

Functional flow without error handling

Before

```
let updateCustomer =
  receiveRequest()
  |> validateRequest
  |> canonicalizeEmail
  |> updateDbFromRequest
  |> sendEmail
  |> returnMessage
```

One track

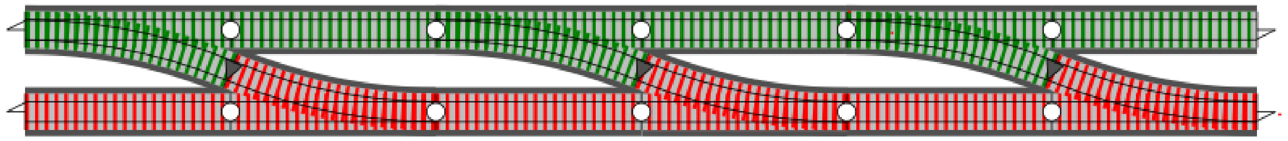


Functional flow with error handling

After

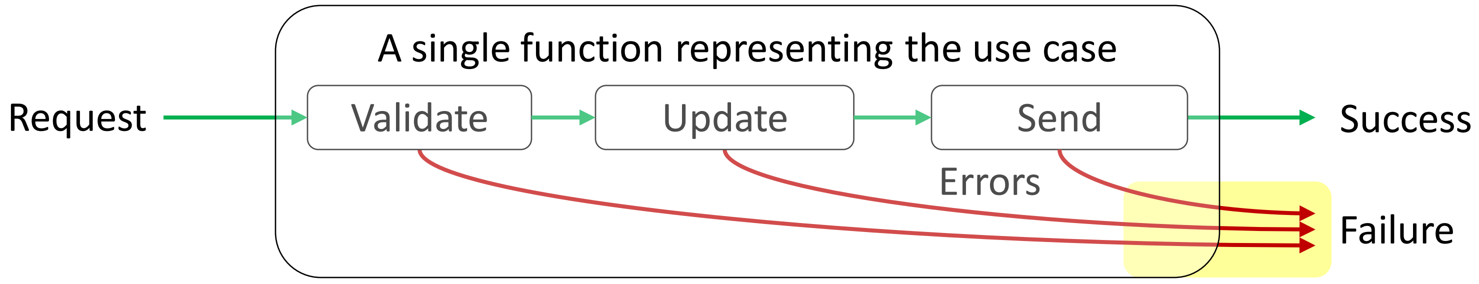
```
let updateCustomerWithErrorHandling =
   receiveRequest()
   |> validateRequest
   |> canonicalizeEmail
   |> updateDbFromRequest
   |> sendEmail
   |> returnMessage
```

Two track



See fsharpforfunandprofit.com/rop

Designing the unhappy path



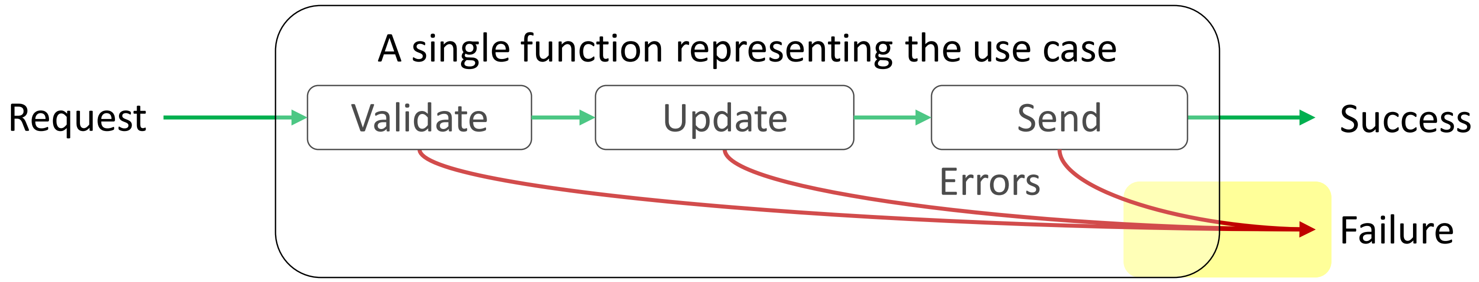
How can a function have more than one output?

Use a choice type!

```
type Result =
    | Ok
    | ValidationError
    | UpdateError
    | SmtpError
```

But maybe too specific for this case?

Functional design

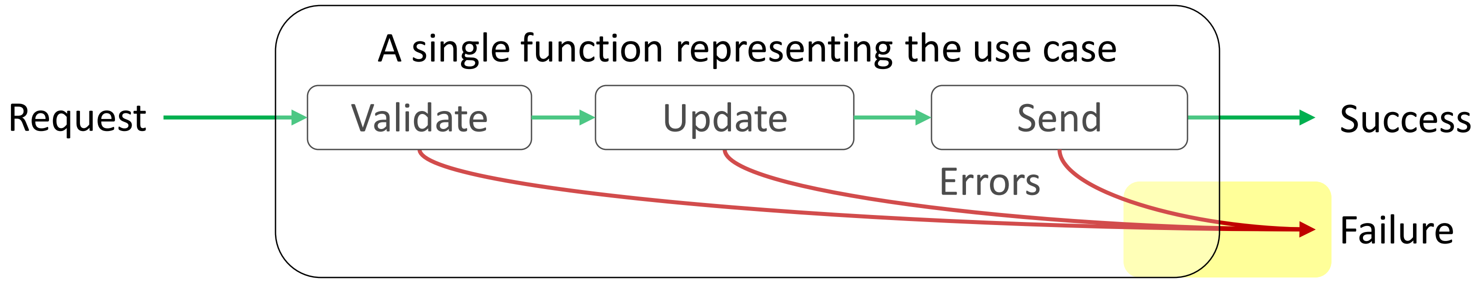


How can a function have more than one output?

```
type Result =
    | Ok
    | Error
```

Much more generic – but no data!

Functional design



How can a function have more than one output?

```
type Result<'SuccessType,'ErrorType> =
    | Ok of 'SuccessType
    | Error of 'ErrorType
```

This is just what we want

Designing for errors

Unhappy paths are requirements too

```
let validateInput input =
   if input.name = "" then
      Error "Name must not be blank"
   else if input.email = "" then
      Error "Email must not be blank"
   else
      Ok input  // happy path
```

```
// returns Result<'Input,string> =
```

Using strings is not good

```
let validateInput input =
   if input.name = "" then
      Error NameMustNotBeBlank
   else if input.email = "" then
      Error EmailMustNotBeBlank
   else
      Ok input  // happy path

type ErrorMessage =
   | NameMustNotBeBlank
   | EmailMustNotBeBlank

// returns Result<'Input,ErrorMessage> =
```

Defined a special type rather than string

```
let validateInput input =
   if input.name = "" then
      Error NameMustNotBeBlank
   else if input.email = "" then
      Error EmailMustNotBeBlank
   else if (input.email doesn't match regex) then
      Error EmailNotValid input.email
   else
      Ok input  // happy path
```

Add invalid
email as data

```
type ErrorMessage =
  | NameMustNotBeBlank
  | EmailMustNotBeBlank
  | EmailNotValid of EmailAddress
```

```
type ErrorMessage =
   | NameMustNotBeBlank
   | EmailMustNotBeBlank
   | EmailNotValid of EmailAddress
```

Documentation of everything that can go wrong --

And it's type-safe documentation that can't go out of date!

Also triggers important DDD conversations

Designing for errors - review

```
type ErrorMessage =
  | NameMustNotBeBlank
  | EmailMustNotBeBlank
  | EmailNotValid of EmailAddress
  // database errors
  | UserIdNotValid of UserId
  | DbUserNotFoundError of UserId
  | DbTimeout of ConnectionString
  | DbConcurrencyError
  | DbAuthorizationError of ConnectionString * Credentials
  // SMTP errors
  | SmtpTimeout of SmtpConnection
  | SmtpBadRecipient of EmailAddress
```

Documentation of everything that can go wrong.

Type-safe -- can't go out of date!

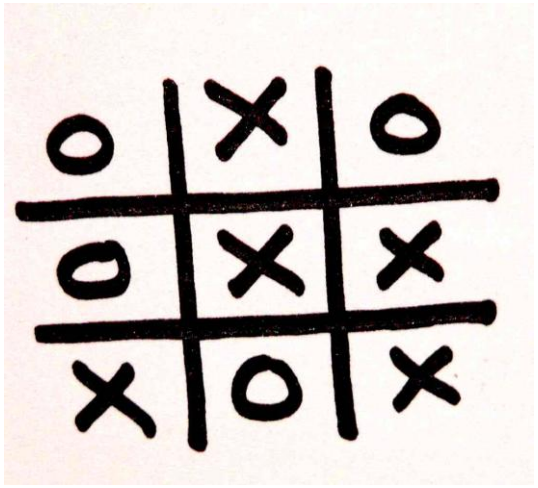
Surfaces hidden requirements.

Test against error codes, not strings.

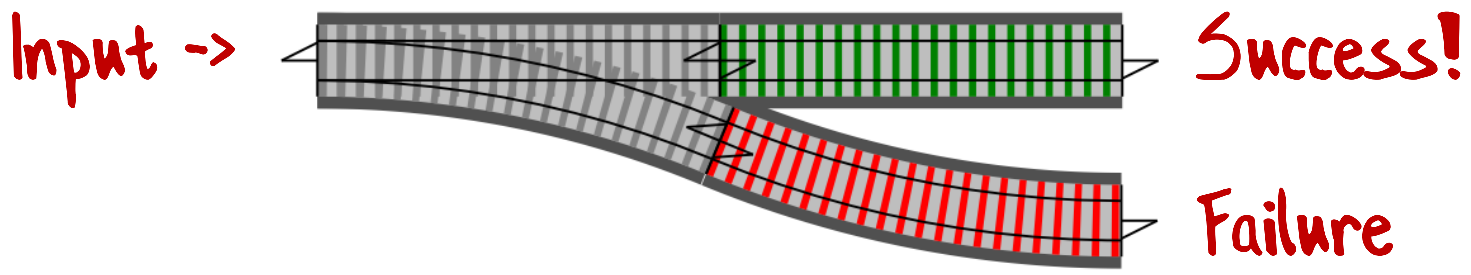
Makes translation easier.

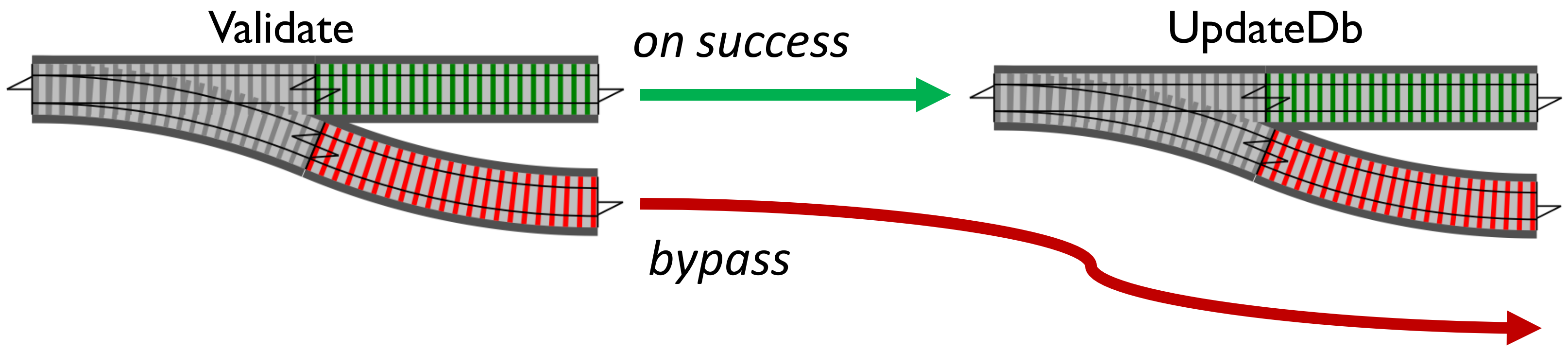
Exercise:
Add errors to the domain models

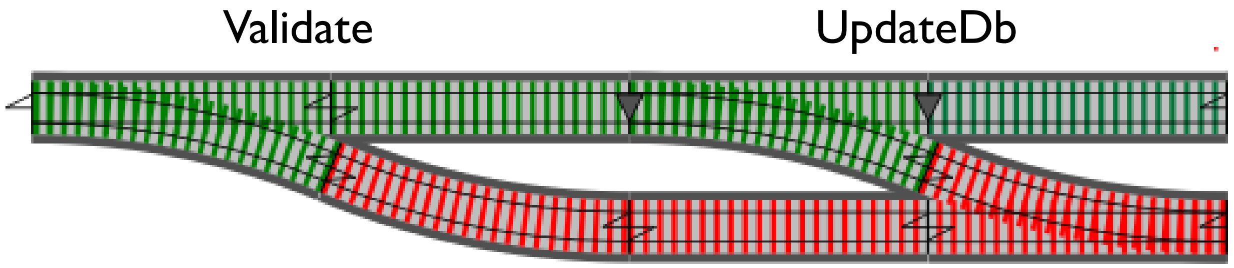
Add errors to the domain models

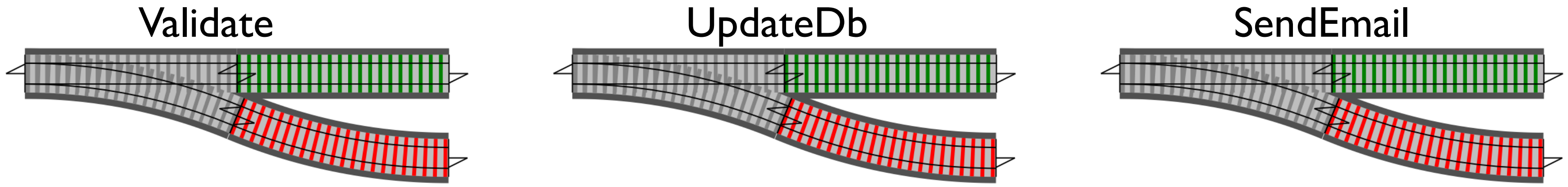


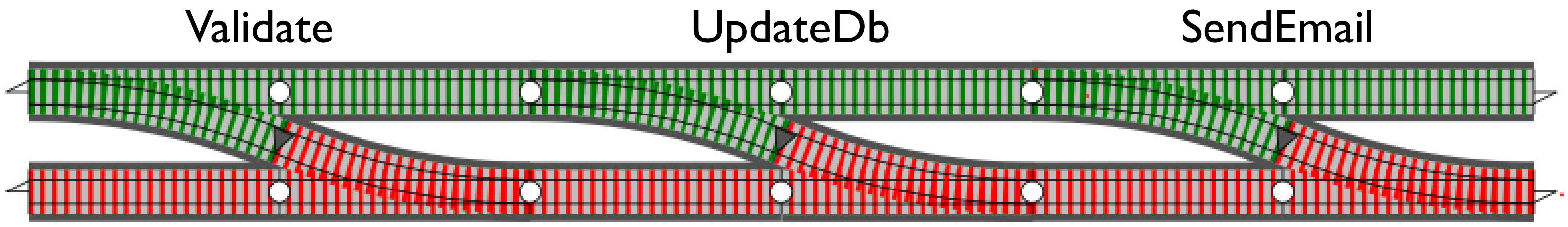
How to implement Railway Oriented Programming


Input ->
Success!
Failure

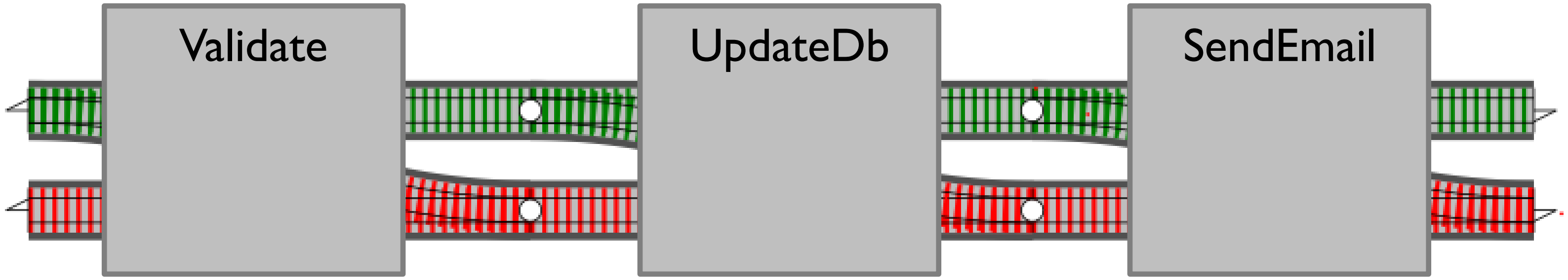

Validate
on success
UpdateDb
bypass


Validate
UpdateDb

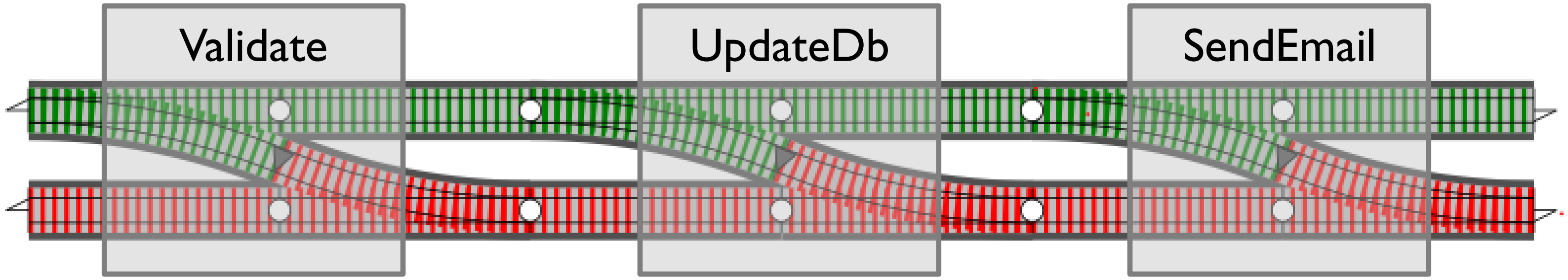

Validate
UpdateDb
SendEmail


Validate
UpdateDb
SendEmail

How to compose these functions?

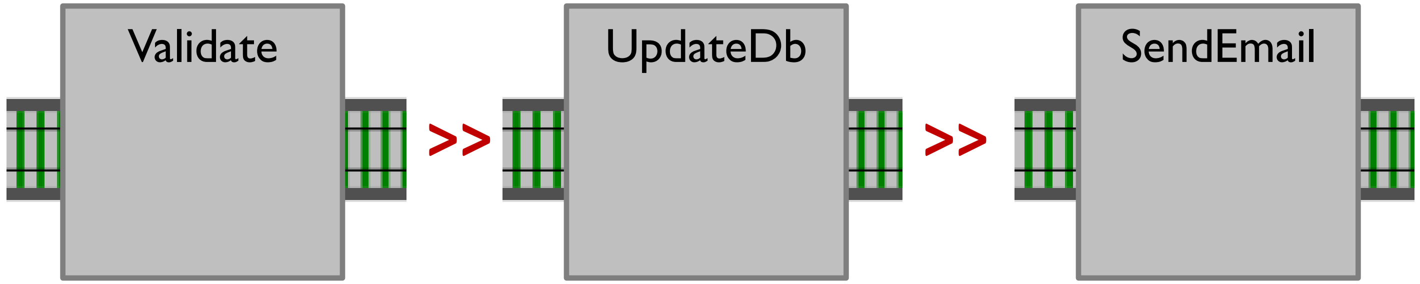


Here we have a series of black box functions that are straddling a two-track railway.

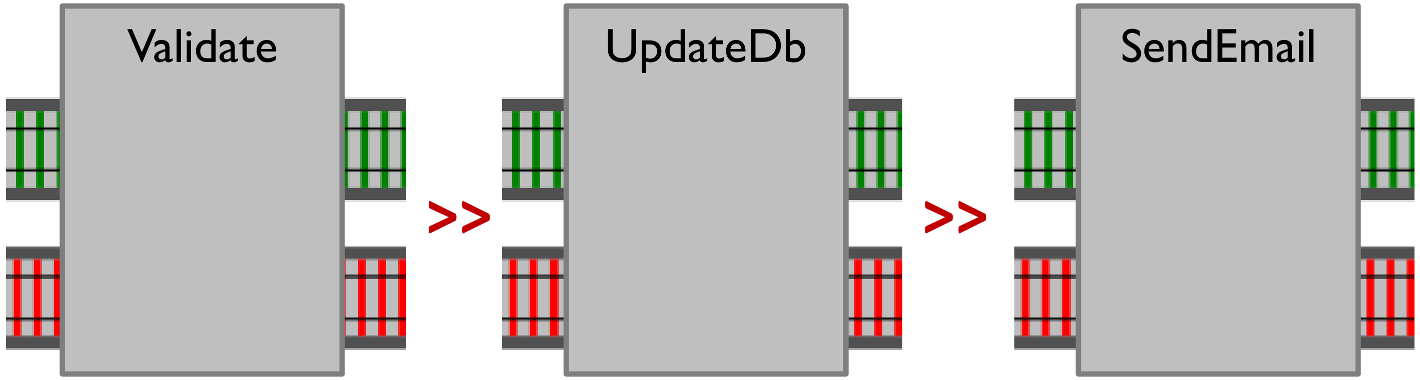


Here we have a series of black box functions that are straddling a two-track railway.

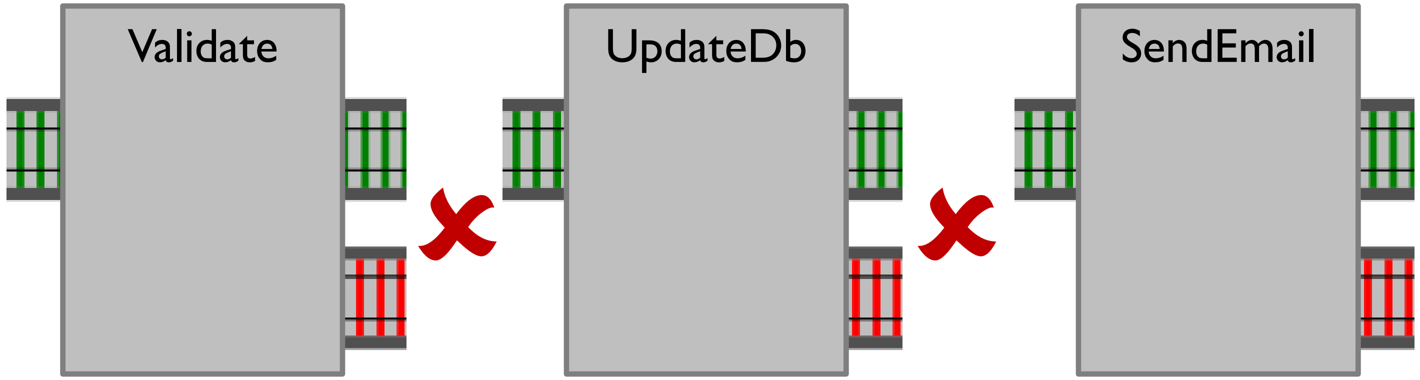
Inside each box there is a switch function.



Composing one-track functions is fine...



... and composing two-track functions is fine...

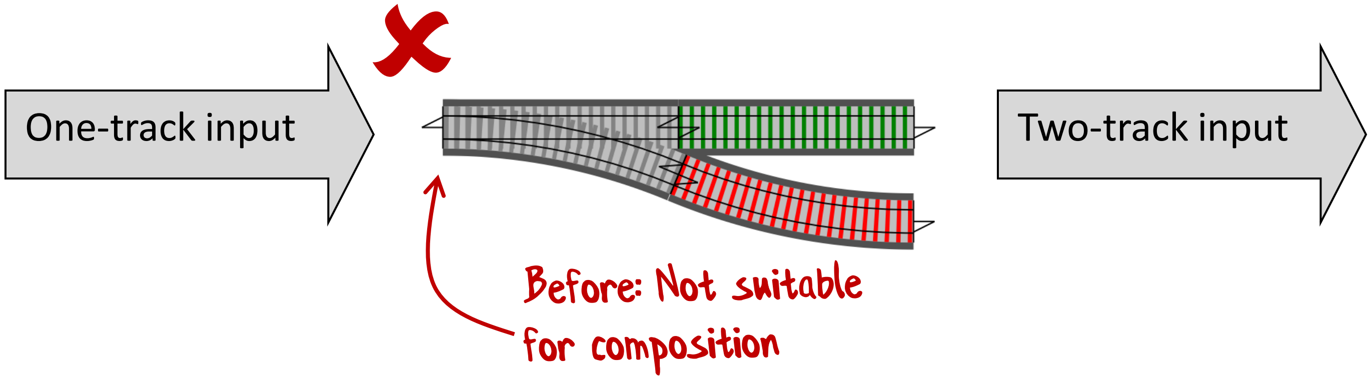


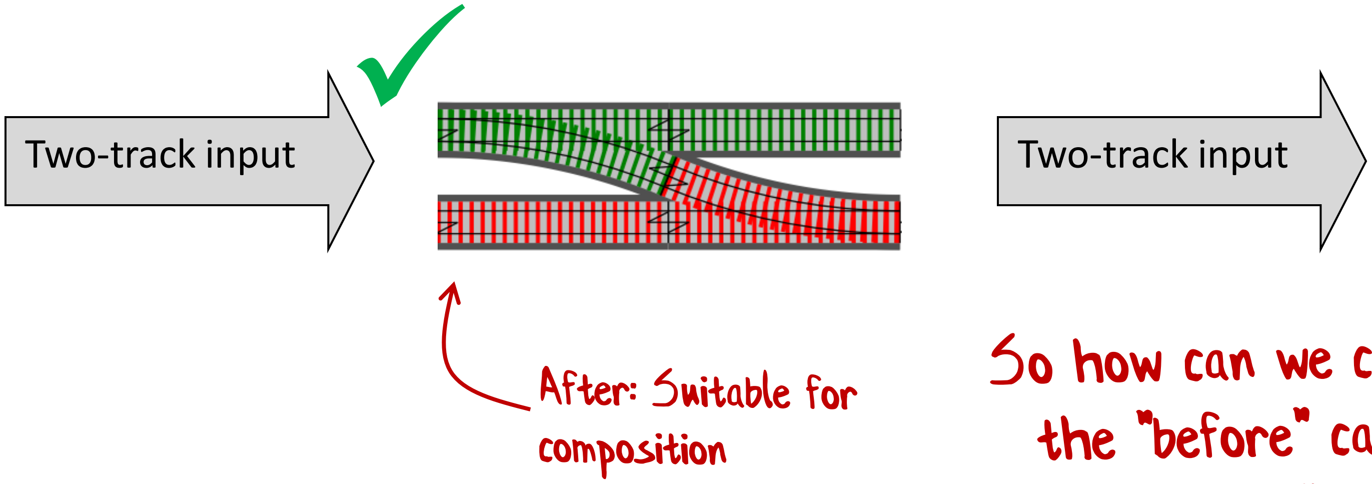
... but composing switches is not allowed!

How to combine the mismatched functions?

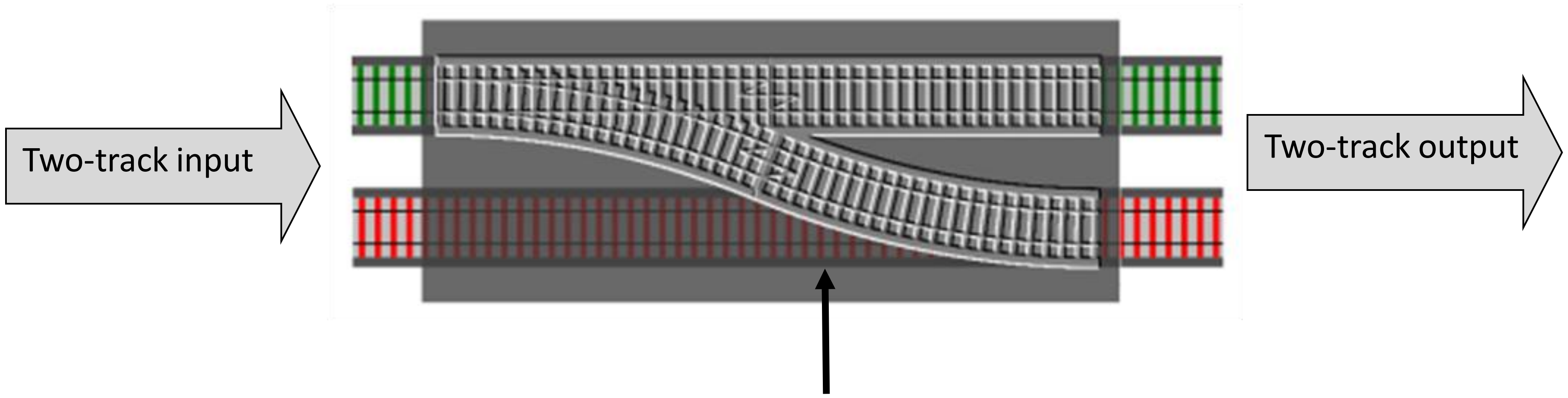
“Bind” is the answer!
Bind all the things!

FP’ers get excited by bind

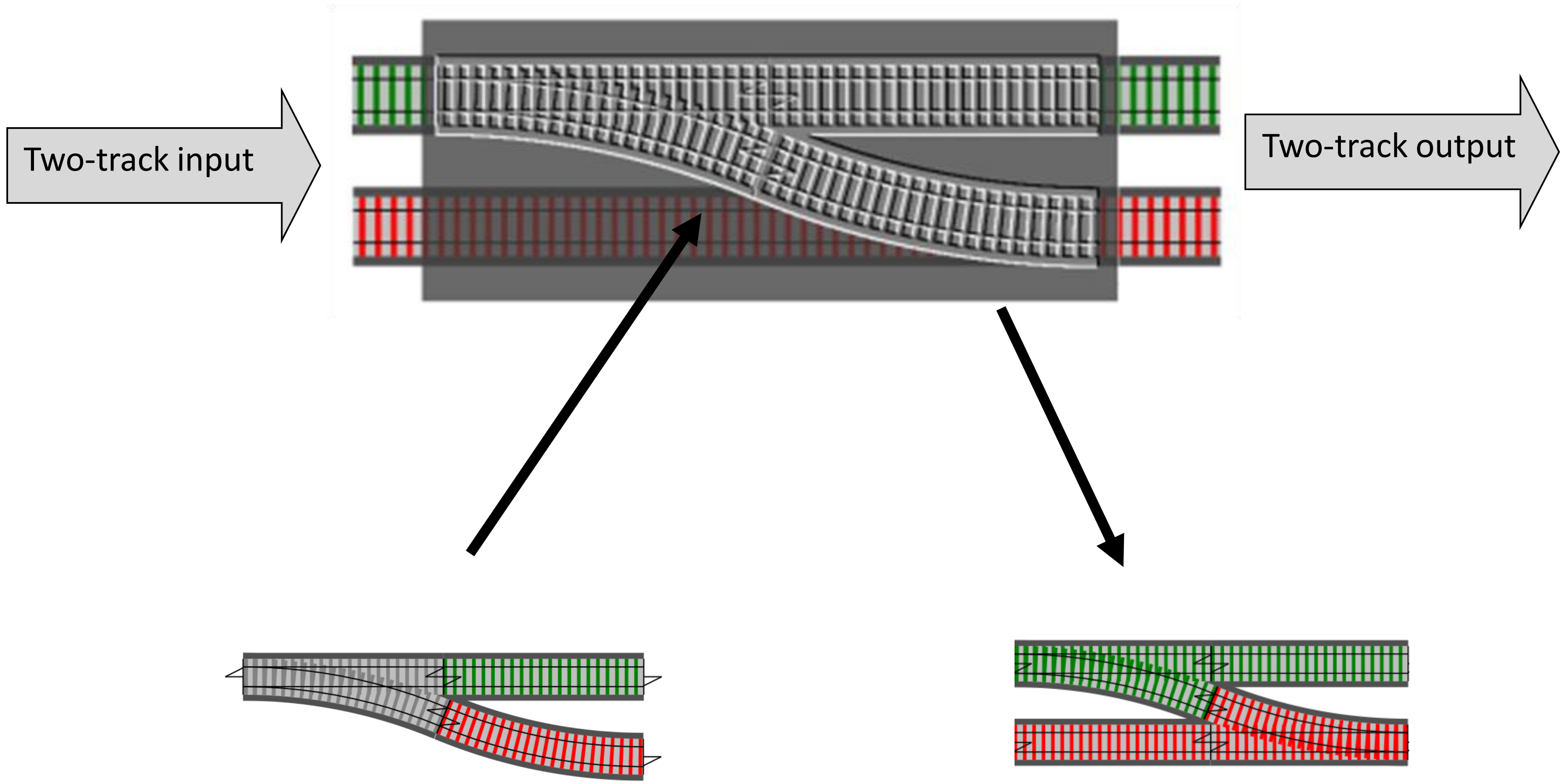


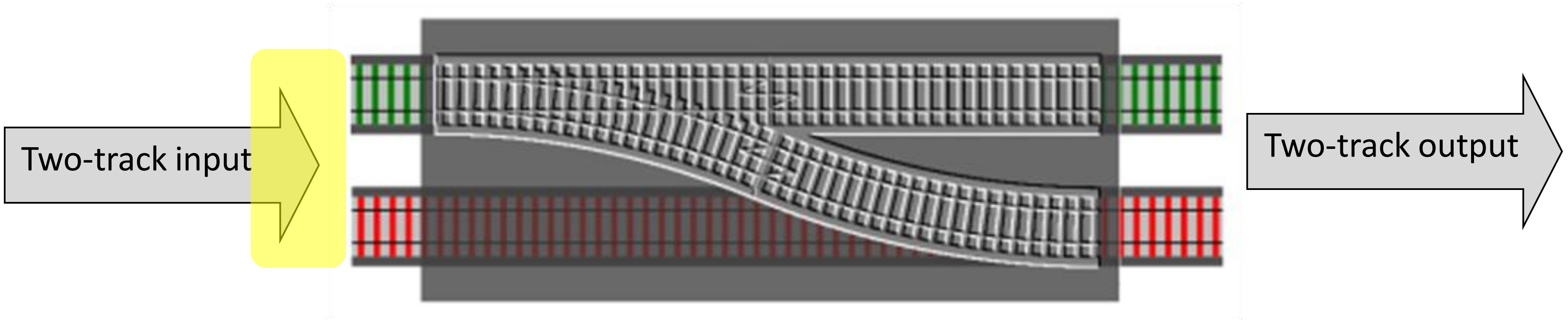


So how can we convert from the "before" case to the "after" case?

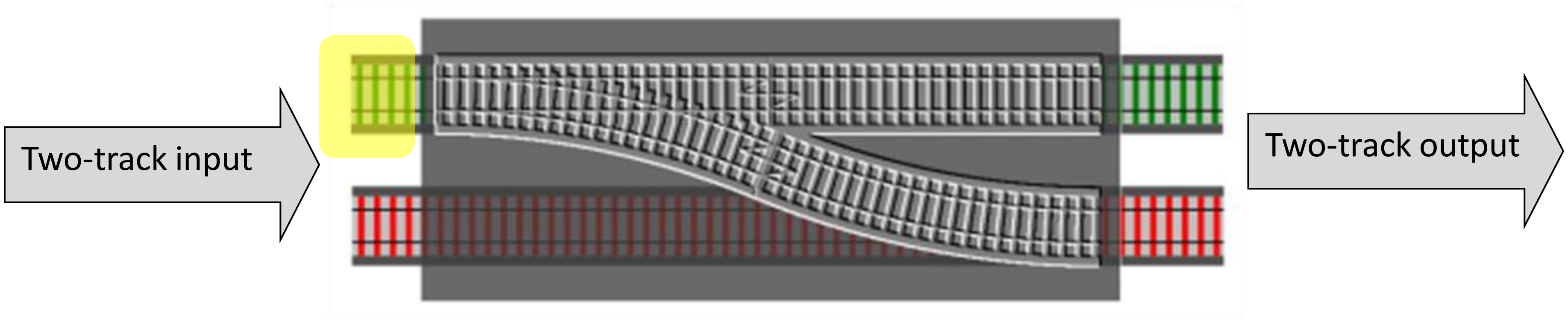


Slot for switch function

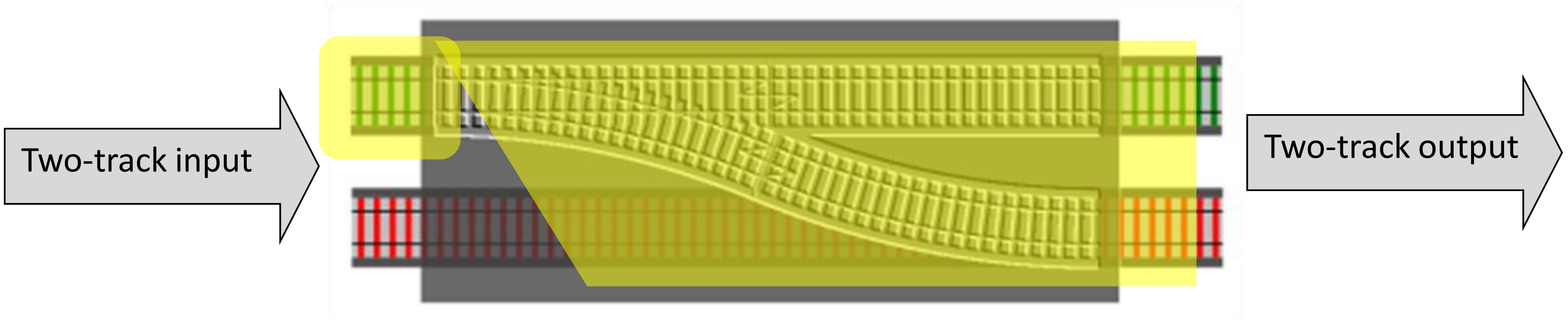

Two-track input
Two-track output



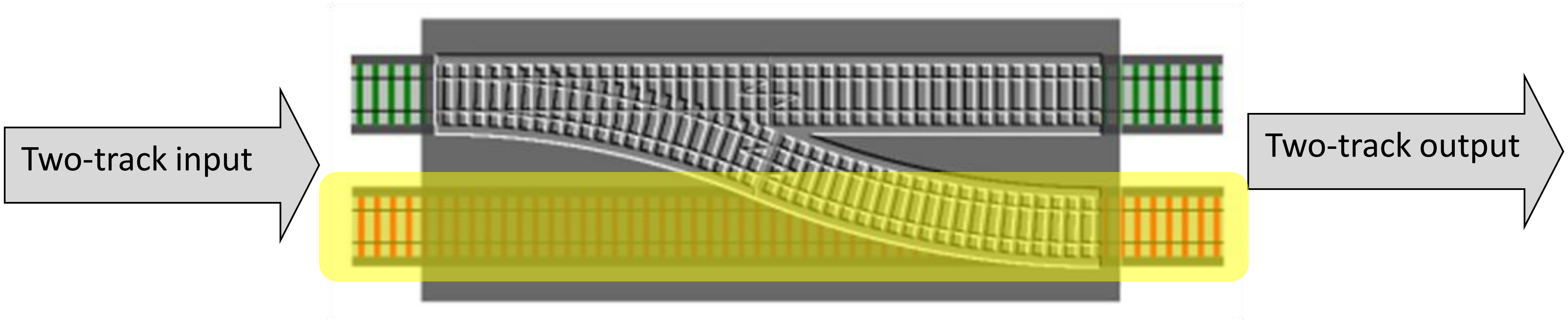
```
let bind nextFunction result =
   match result with
   | Ok s -> nextFunction s
   | Error e -> Error e
```



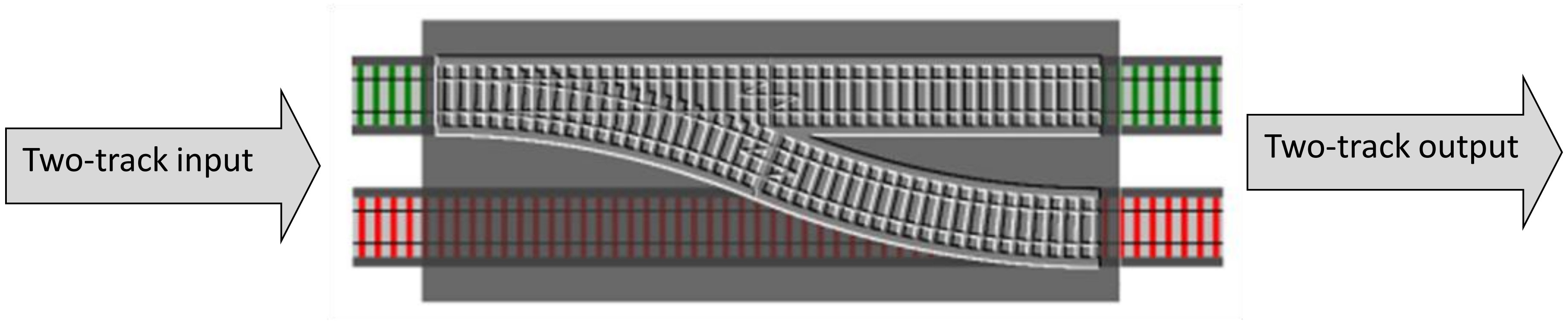
```
let bind nextFunction result =
   match result with
   | Ok s -> nextFunction s
   | Error e -> Error e
```



```
let bind nextFunction result =
   match result with
   | Ok s -> nextFunction s
   | Error e -> Error e
```



```
let bind nextFunction result =
   match result with
    | Ok s -> nextFunction s
    | Error e -> Error e
```



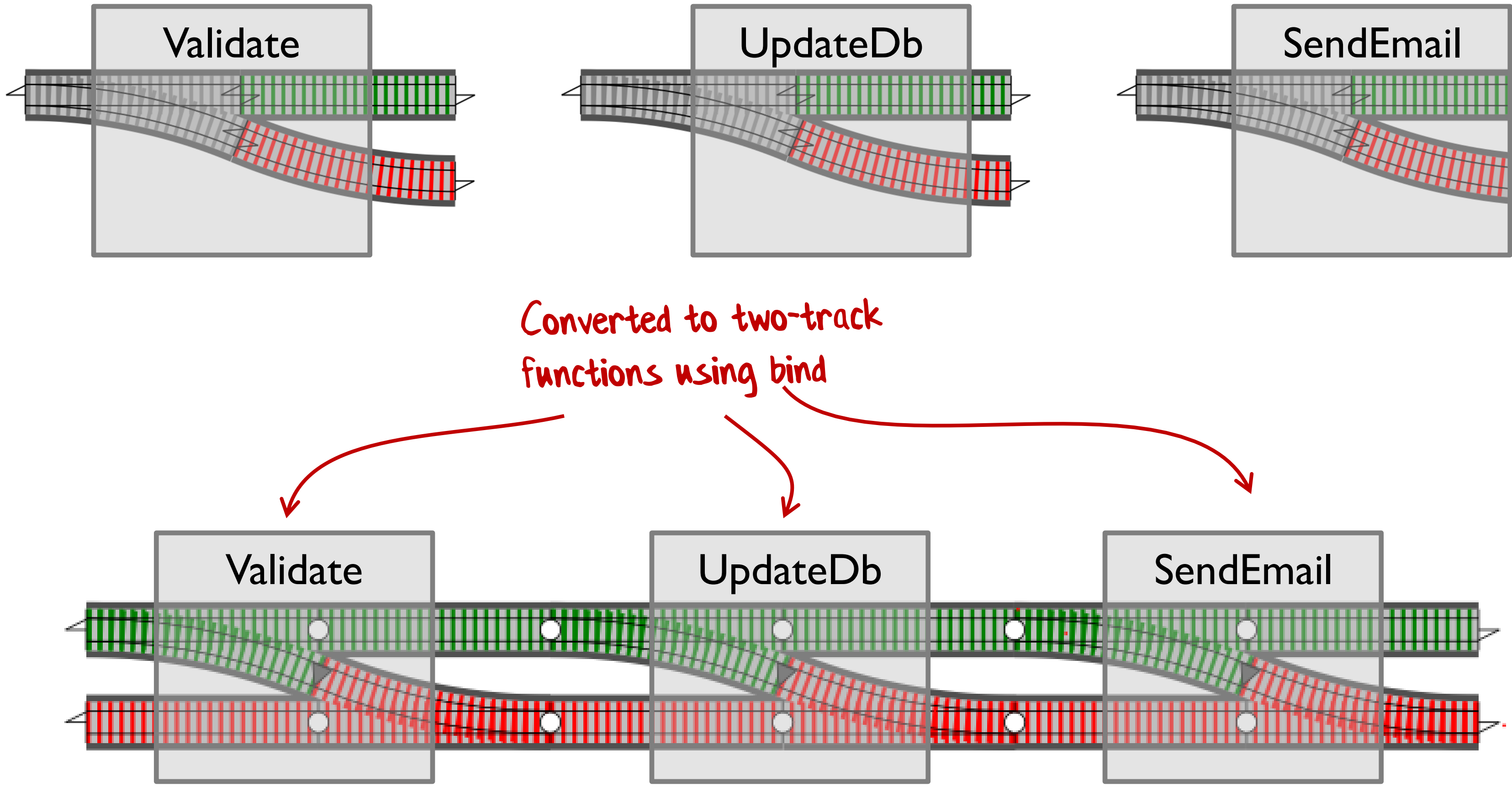
```
Result.bind : ('a -> Result<'b>) -> Result<'a> -> Result<'b>
```

Switch function

2-track input

2-track output

Composing switches - review



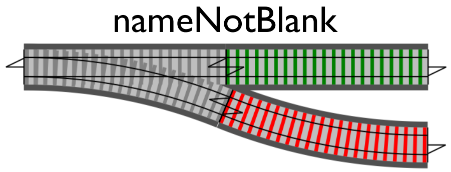
Bind example

Validating input

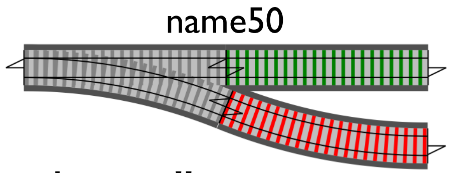
```
type Request = {
   Name : string
   Email : string
}
```

Is this data valid?

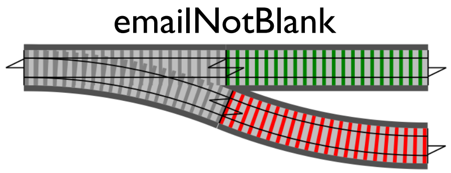
```
let checkNameNotBlank input =
  if input.Name = "" then
     Error "Name must not be blank"
  else Ok input
```

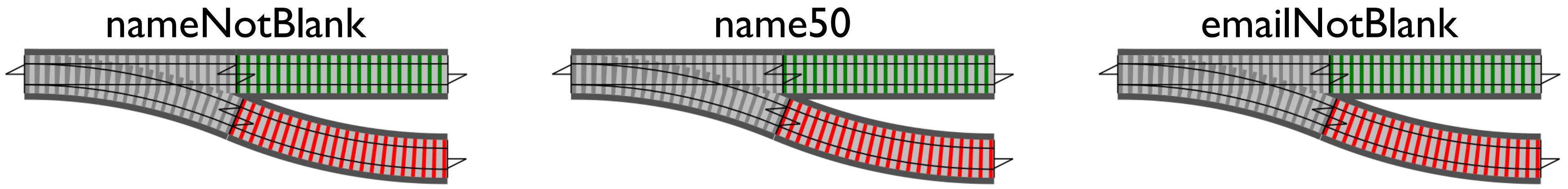


```
let checkName50 input =
  if input.Name.Length > 50 then
     Error "Name must not be longer than 50 chars"
  else Ok input
```

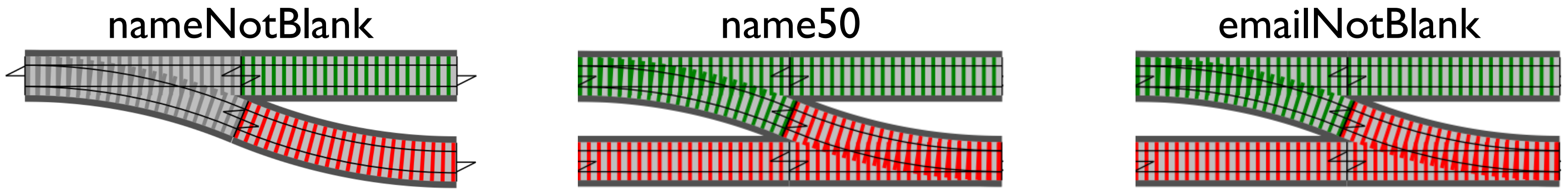


```
let checkEmailNotBlank input =
  if input.Email = "" then
     Error "Email must not be blank"
  else Ok input
```



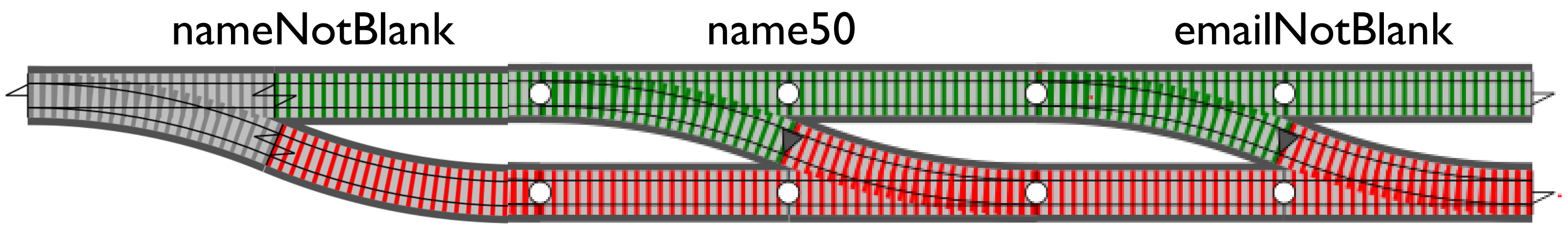


```
checkNameNotBlank (combined with)
checkName50 (combined with)
checkEmailNotBlank
```



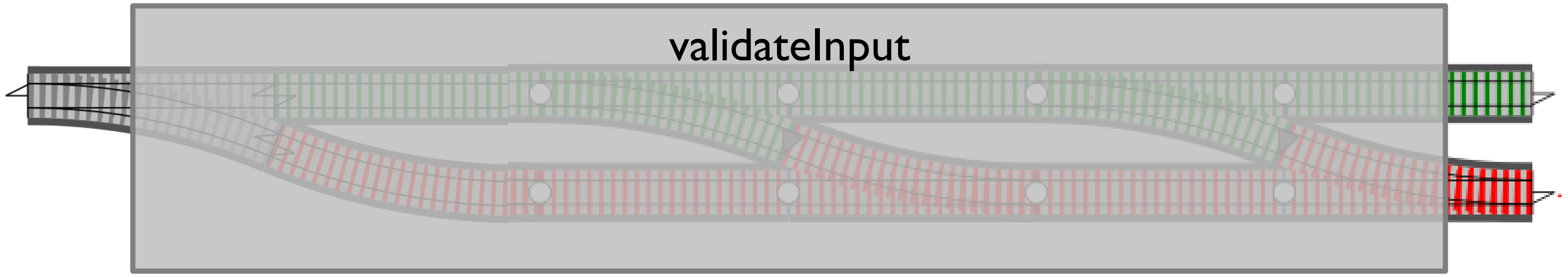
```
checkNameNotBlank
          bind checkName50
                   bind checkEmailNotBlank
```

use "bind" to
convert to 2-track



```
request
|> checkNameNotBlank
|> Result.bind checkName50
|> Result.bind checkEmailNotBlank
```

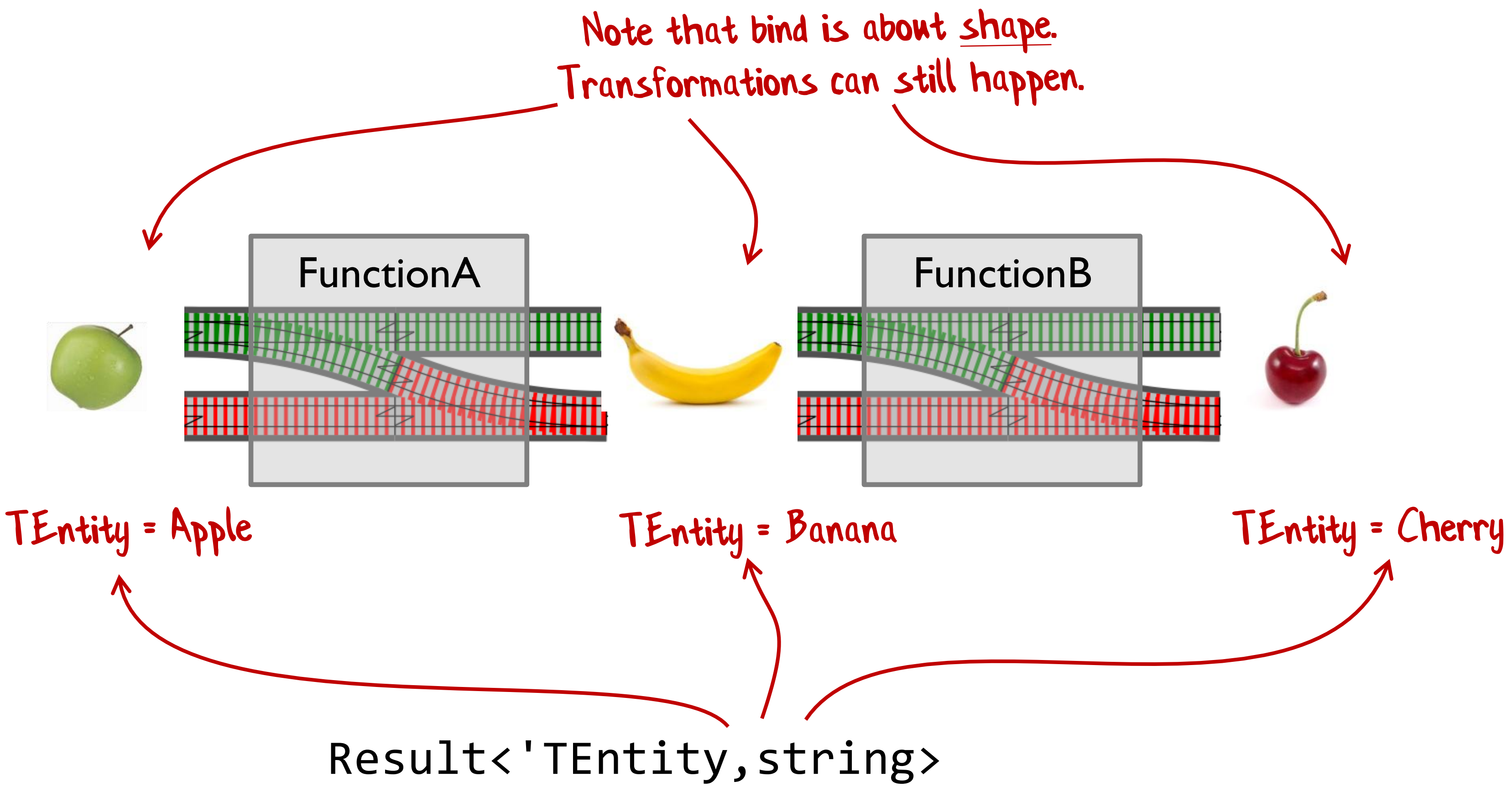
then compose together

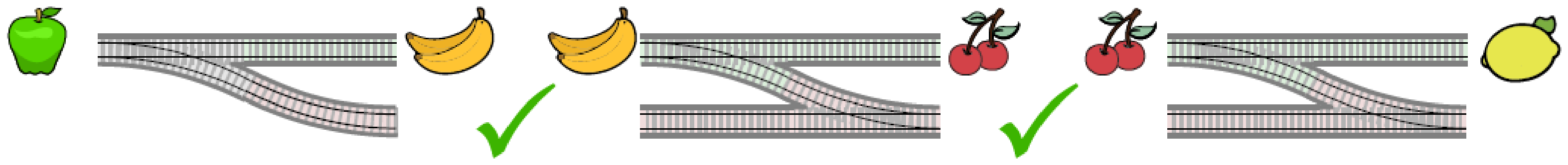


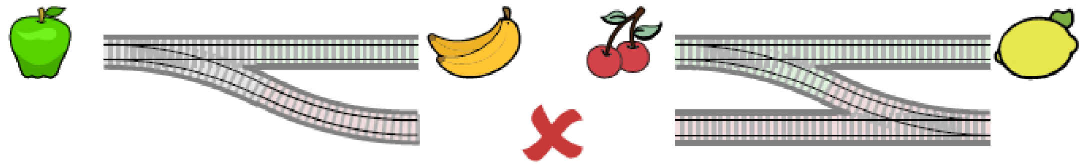
Define a function

```
let validateInput input =
   input
   |> checkNameNotBlank
   |> Result.bind checkName50
   |> Result.bind checkEmailNotBlank
```

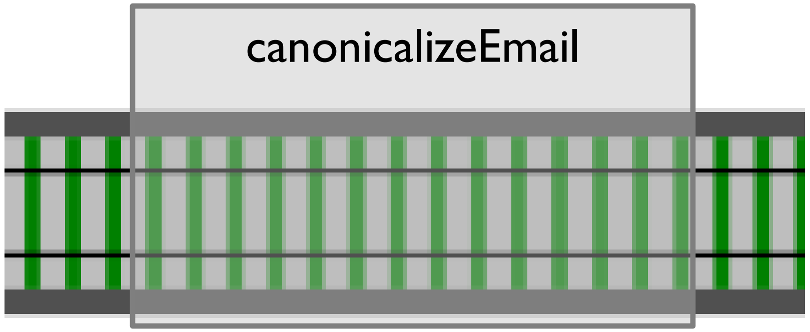
Overall result is a new two-track function


Note that bind is about shape.
Transformations can still happen.
FunctionA
FunctionB
TEntity = Apple
TEntity = Banana
TEntity = Cherry
Result<'TEntity,string>



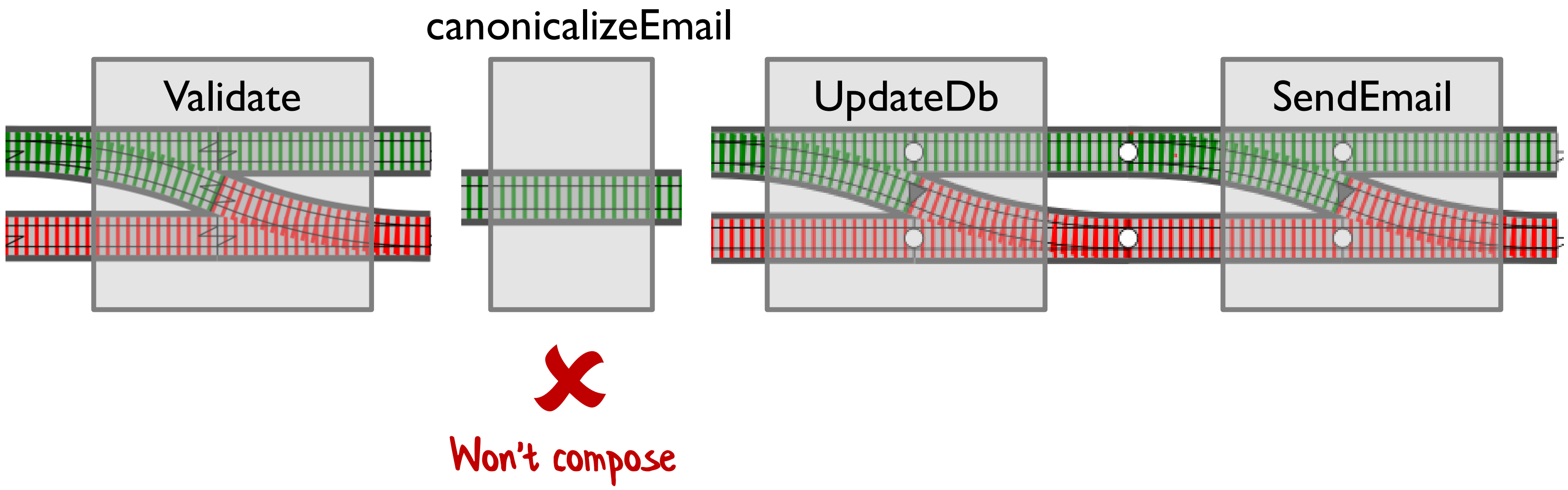


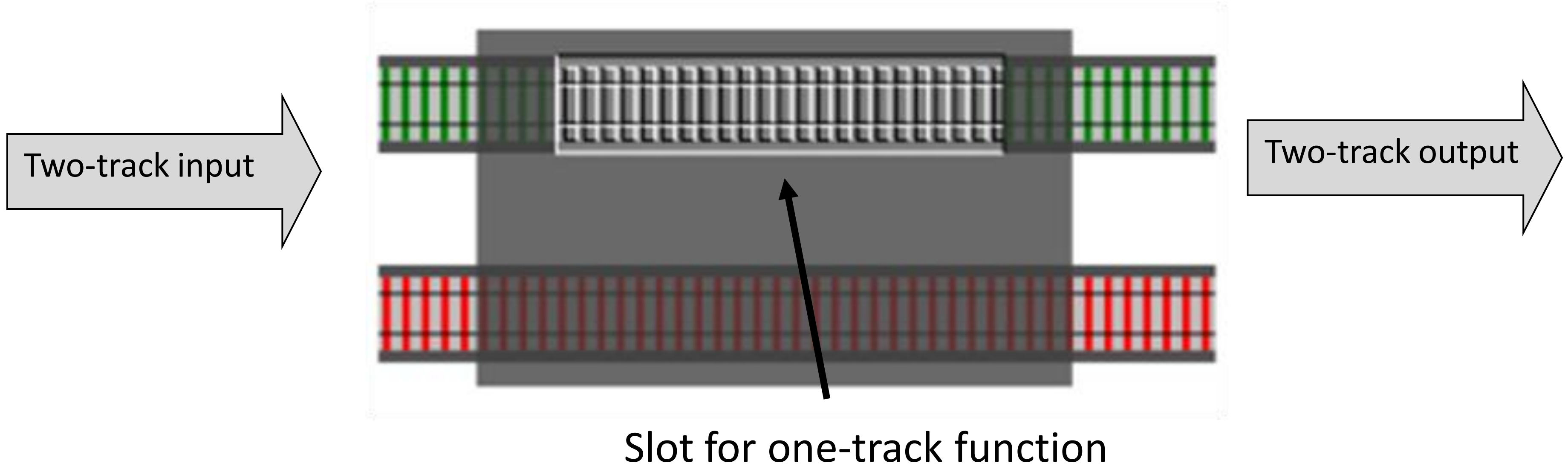
Mapping the success track

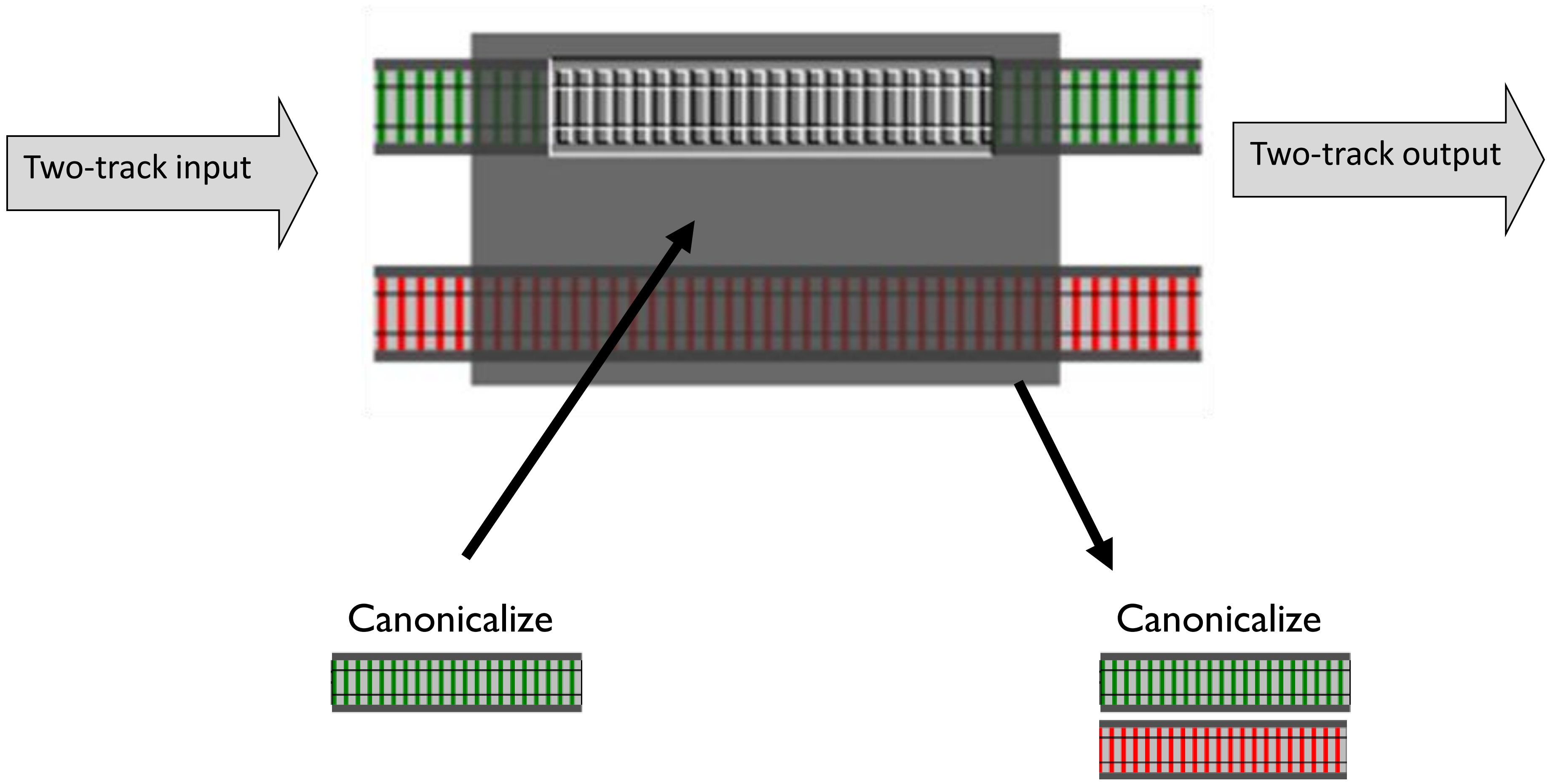


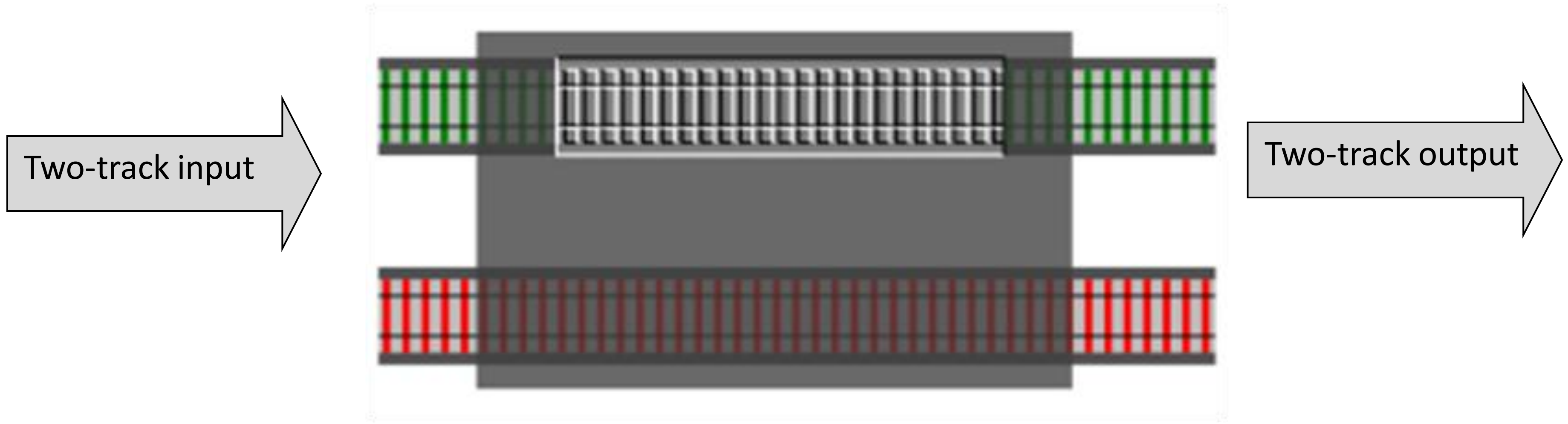
```
// trim spaces and lowercase
let canonicalizeEmail input =
   { input with email = input.email.Trim().ToLower() }
```

A simple function that doesn't generate errors – a "one-track" function.

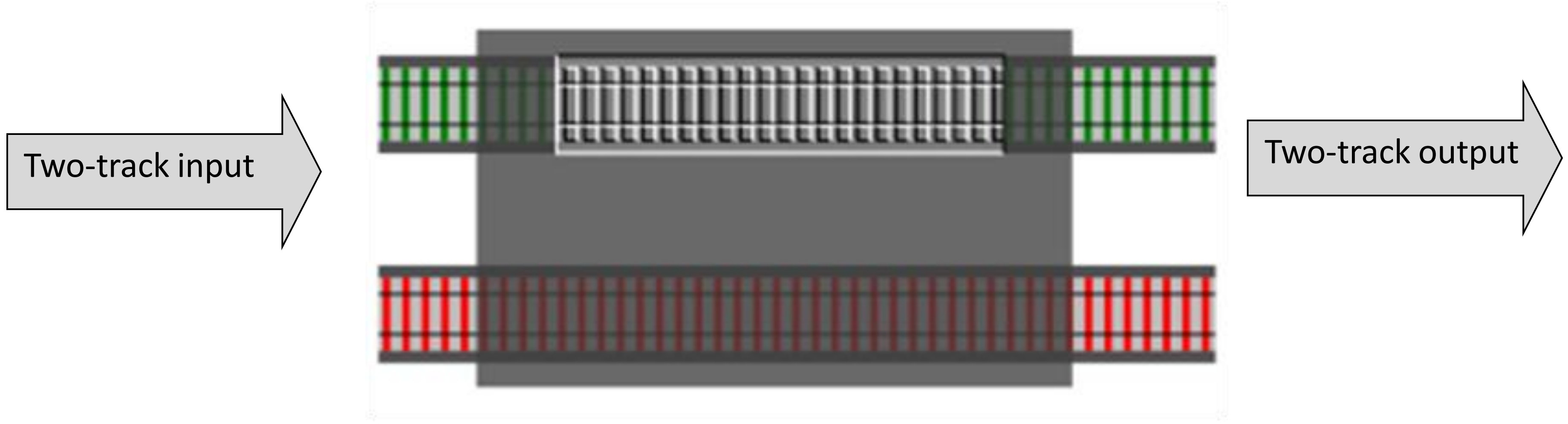

canonicalizeEmail
Validate
UpdateDb
SendEmail
Won't compose


Two-track input
Two-track output
Slot for one-track function


Two-track input
Two-track output
Canonicalize
Canonicalize



```
let map singleTrackFunction twoTrackInput =
  match twoTrackInput with
  | Ok s -> Ok (singleTrackFunction s)
  | Error f -> Error f
```



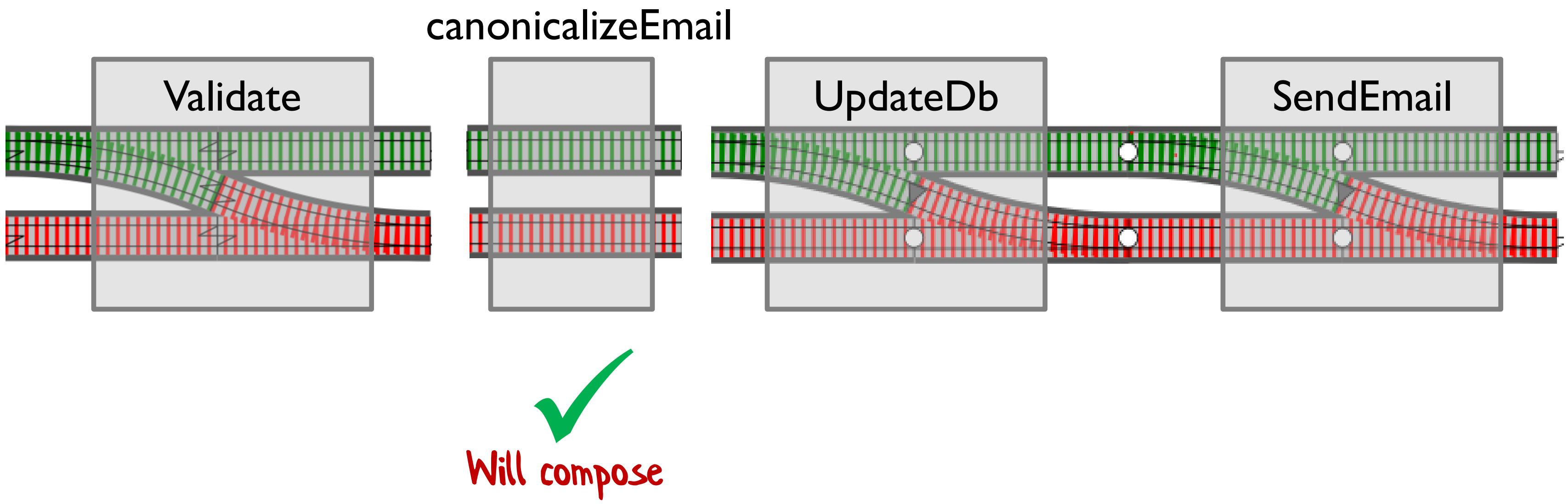
```
Result.map : ('a -> 'b) -> Result<'a,'c> -> Result<'b,'c>
```

Single track function

2-track input

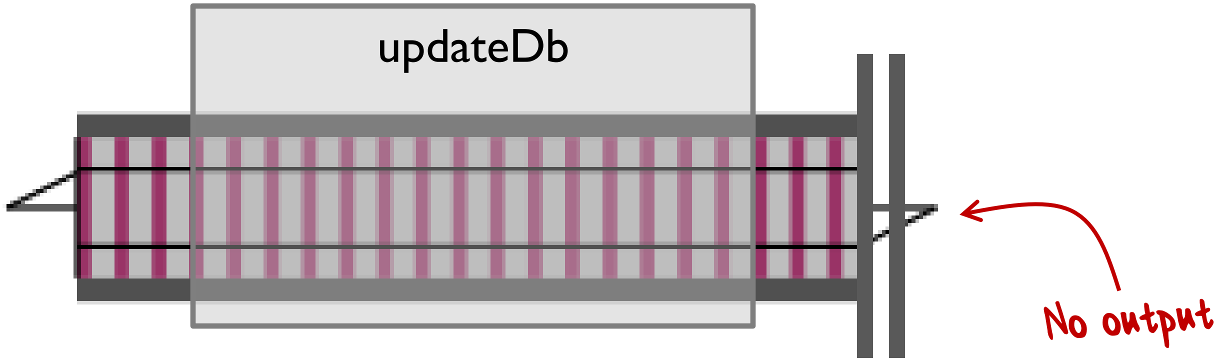
2-track output

Converting one-track functions



Converting dead-end functions

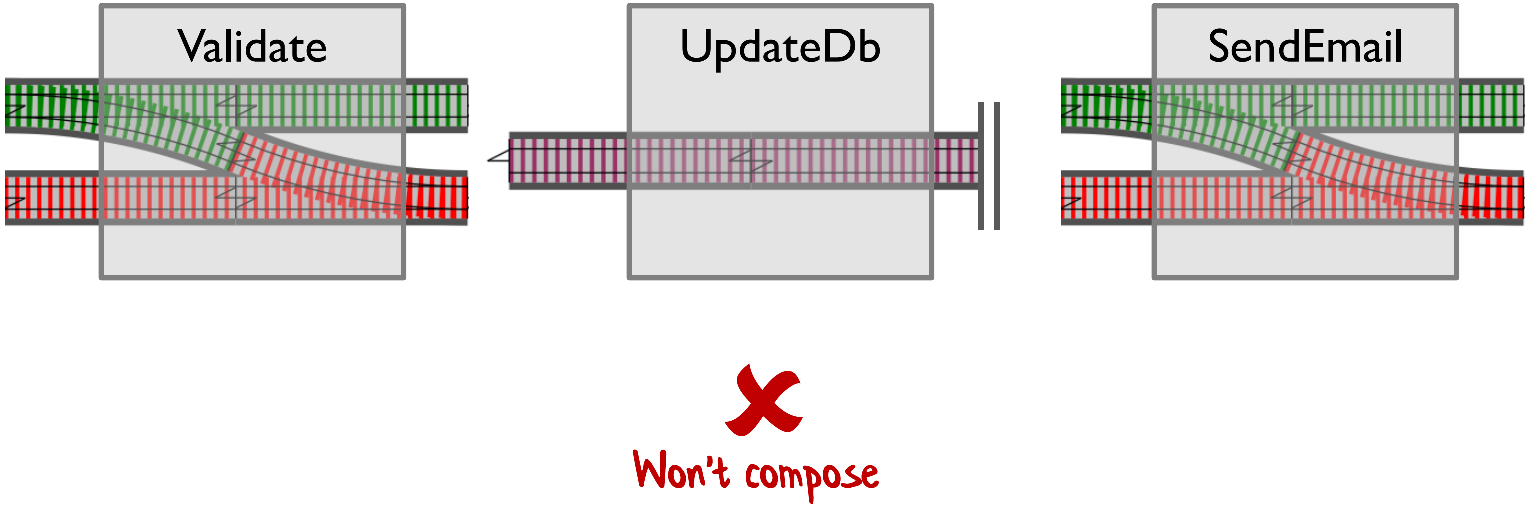
Converting dead-end functions



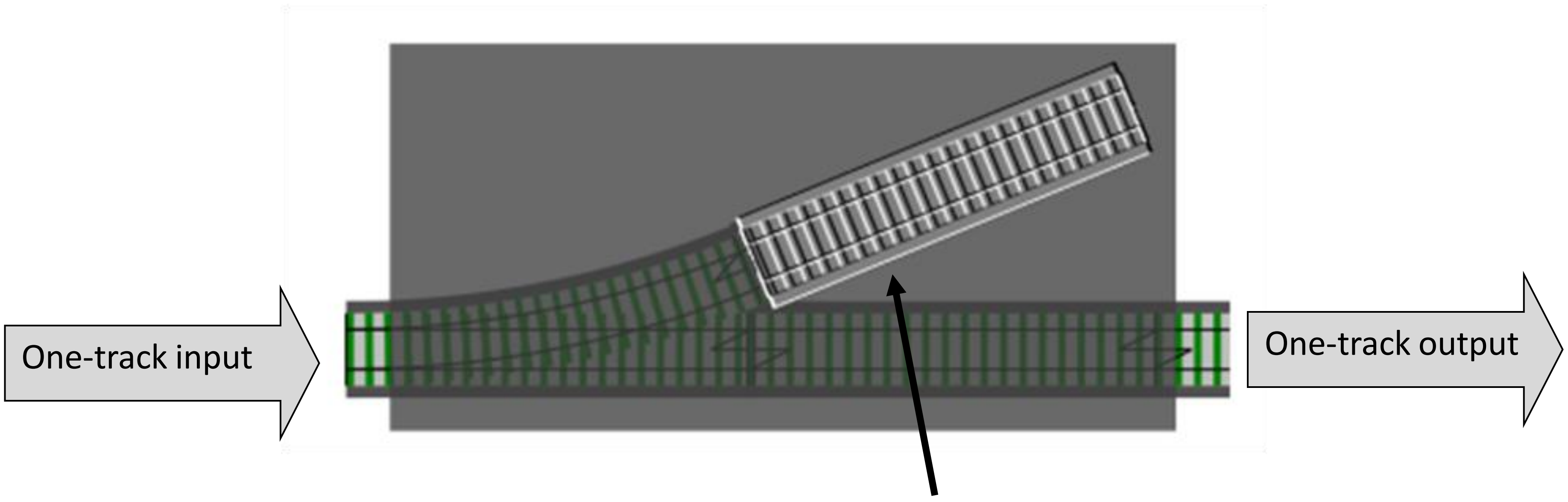
```
let updateDb request =
    // do something
    // return nothing at all
```

A function that doesn't return anything— a "dead-end" function.

Converting dead-end functions

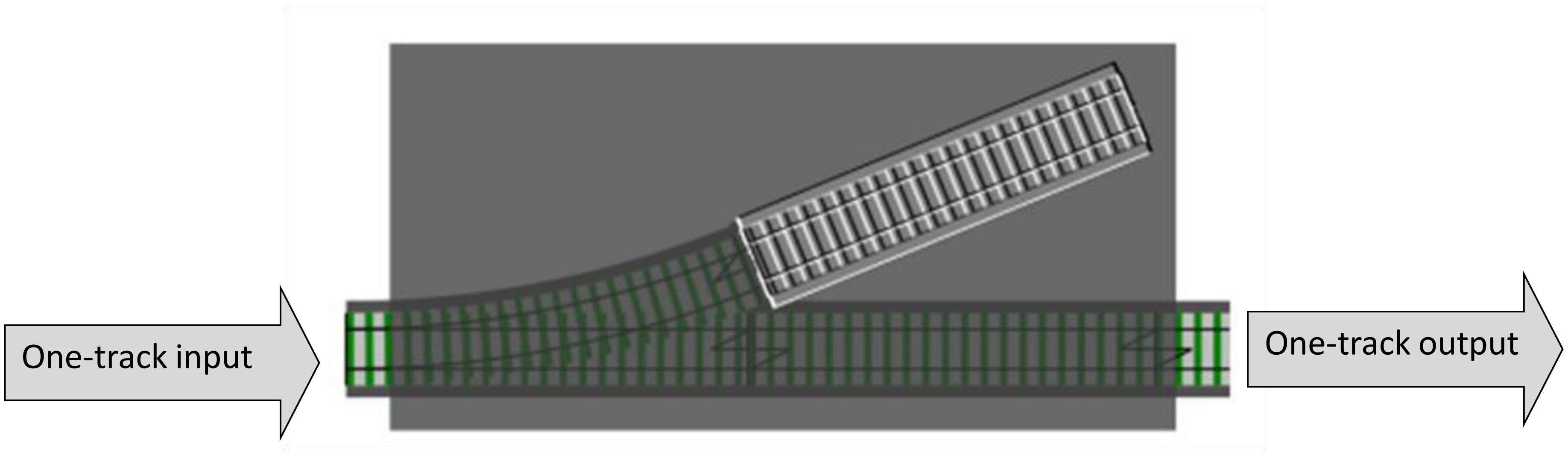


Converting dead-end functions



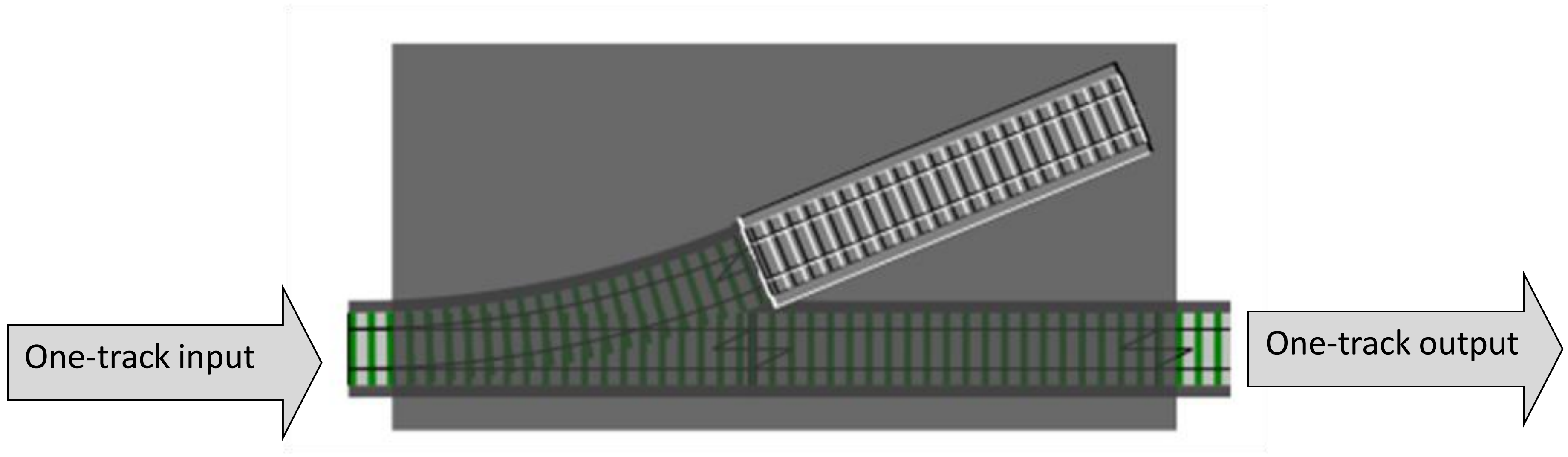
Slot for dead end function

Converting dead-end functions



```
let tee deadEndFunction oneTrackInput =
    deadEndFunction oneTrackInput
    oneTrackInput
```

Converting dead-end functions



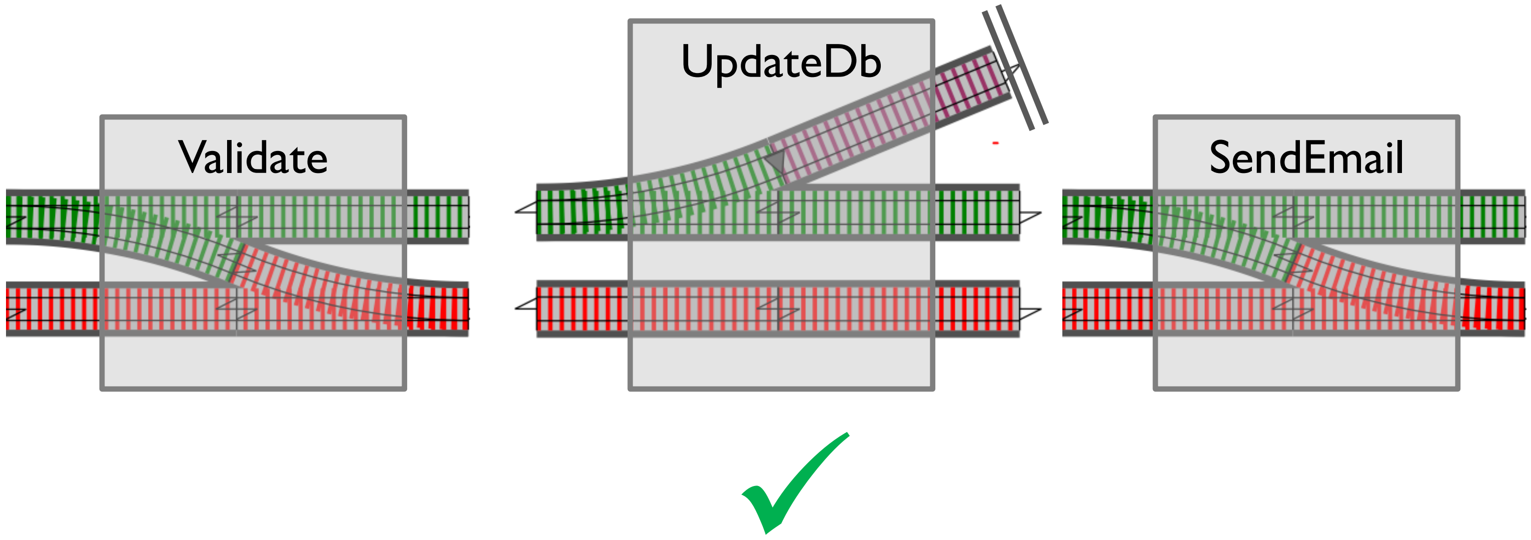
```
tee : ('a -> unit) -> 'a -> 'a
```

Dead end function

one-track input

one-track output

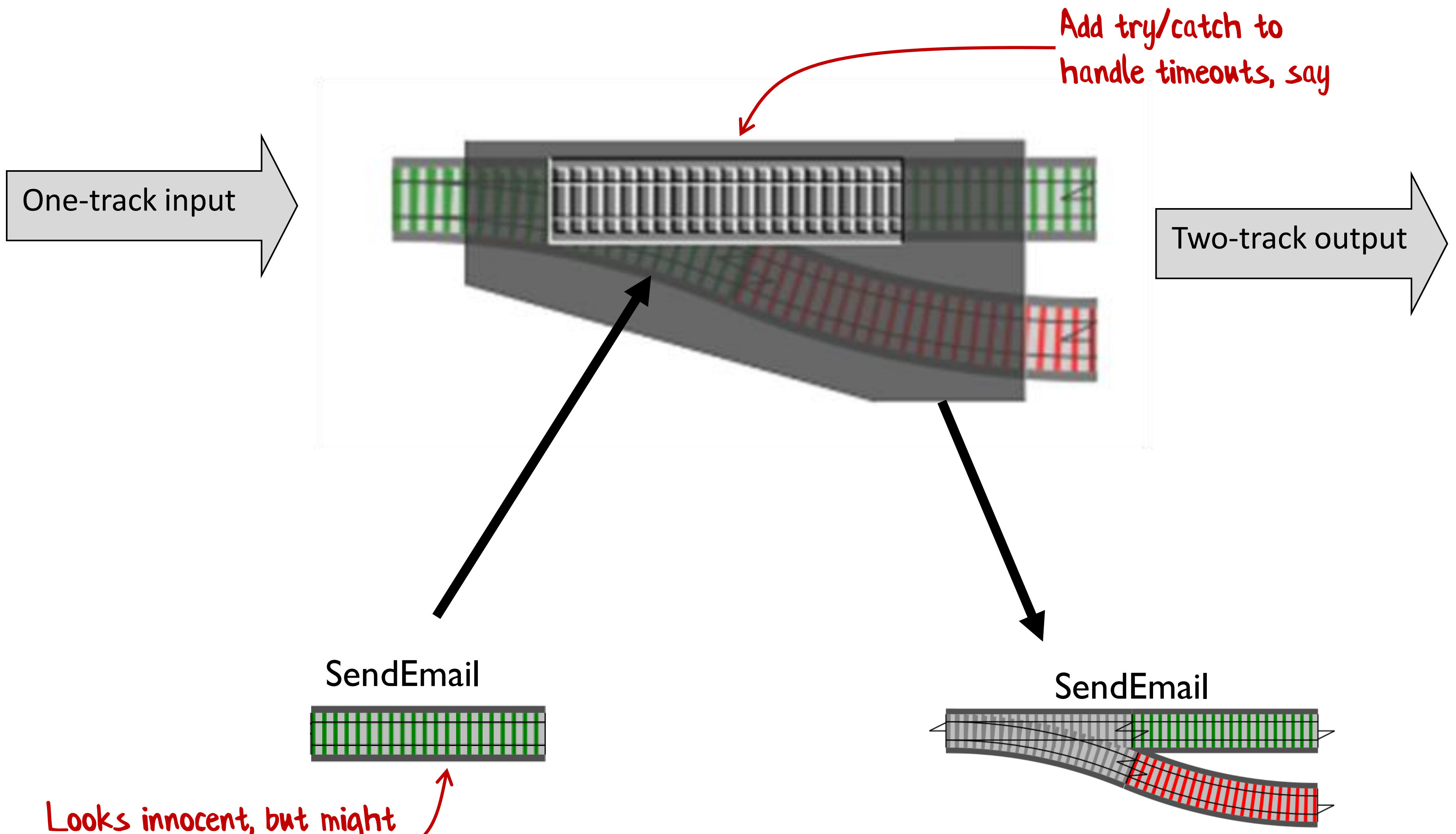
Converting dead-end functions



Will compose

Functions that throw exceptions

Functions that throw exceptions



Looks innocent, but might throw an exception

Don't bother handling all possible exceptions:
E.g. FileNotFound, yes. OutOfMemory, no.

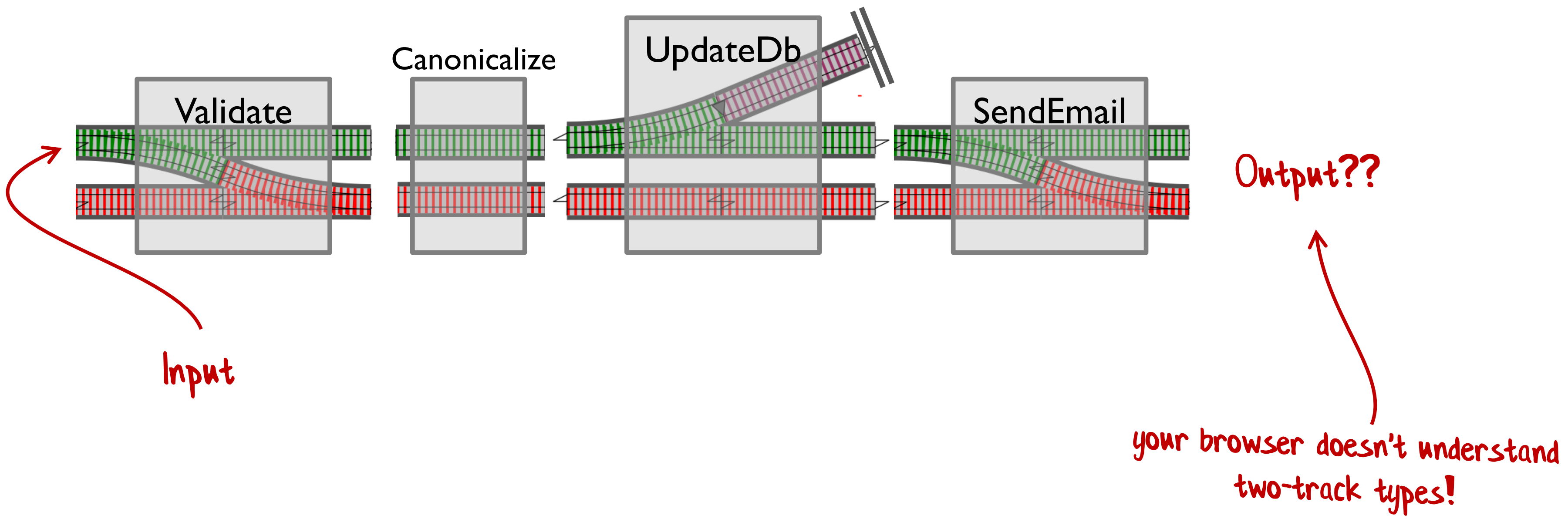
Guideline: Convert exceptions into Failures

Even Yoda recommends not to use exception handling for control flow:

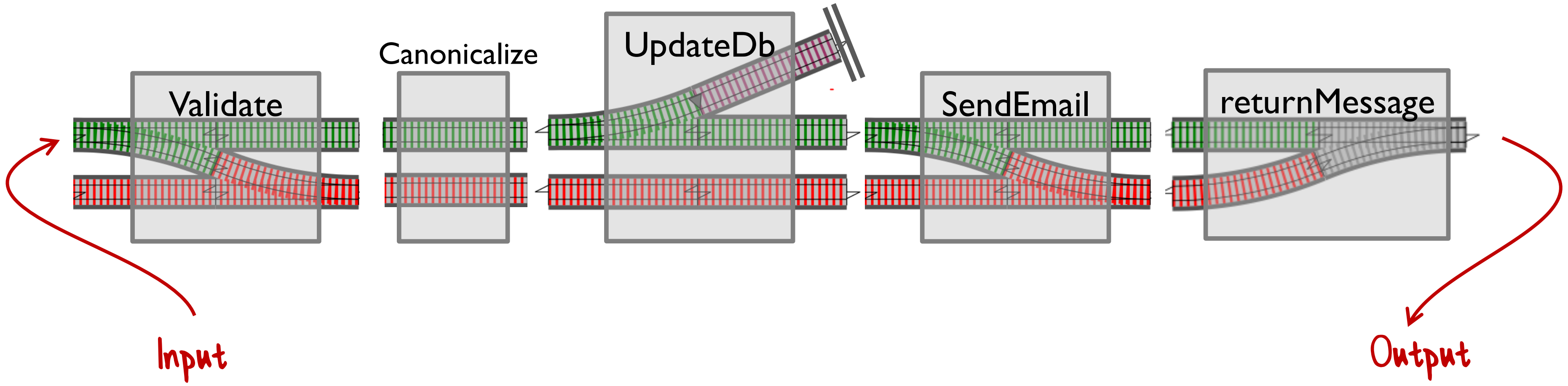
"Do or do not, there is no try".

Putting it all together

Putting it all together



Putting it all together



```
let returnMessage result =
  match result with
  | Ok obj -> OK obj.ToJson()
  | Error msg -> BadRequest msg
```

(demo)

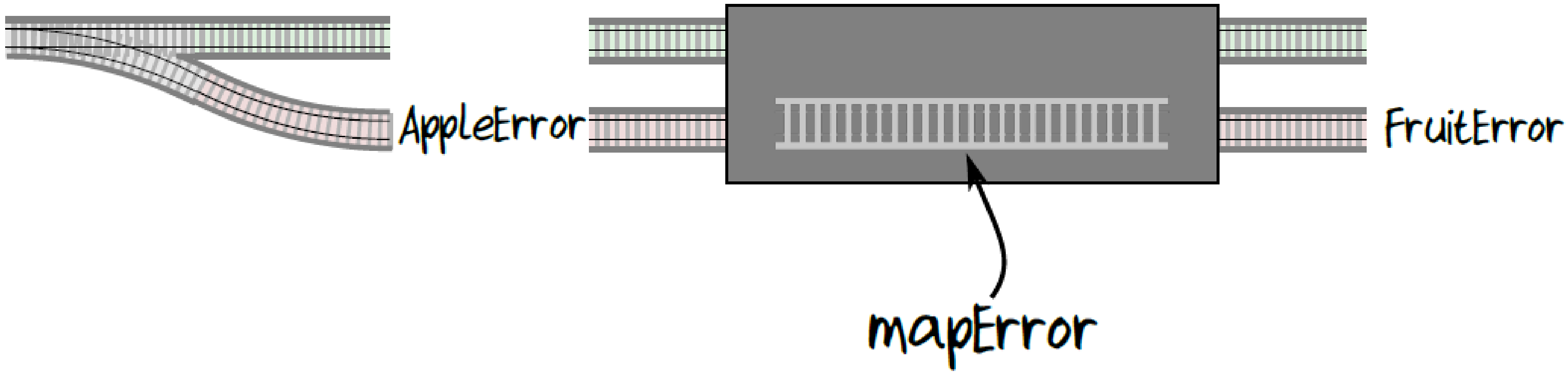
Mapping the error track

Converting to a common error type

Make sure all errors are the same type

- The error track has the same type all the way along the track.
- So, we may need to change the error types to make them compatible.
- This what "`Result.mapError`" is for

```
type FunctionA =
   Apple -> Result<Bananas,AppleError>
type FunctionB =
   Bananas -> Result<Cherries,BananaError>



// define a common superset
type FruitError =
| AppleErrorCase of AppleError
| BananaErrorCase of BananaError
```

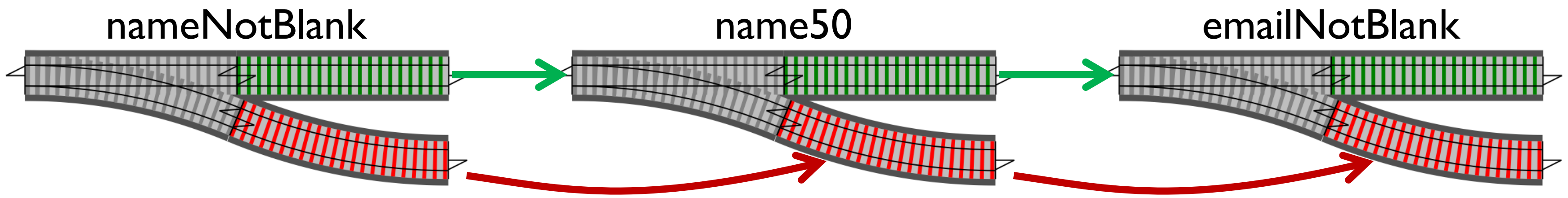

AppleError
FruitError
mapError

```
let functionAWithFruitError input =
  input
  |> functionA
  |> Result.mapError (fun appleError ->
          AppleErrorCase appleError)

// Apple -> Result<Bananas,FruitError>

// do the same for the other function
// Bananas -> Result<Cherries,FruitError>

// now they can be composed!
```

Demo and exercises 02, 03

Validation

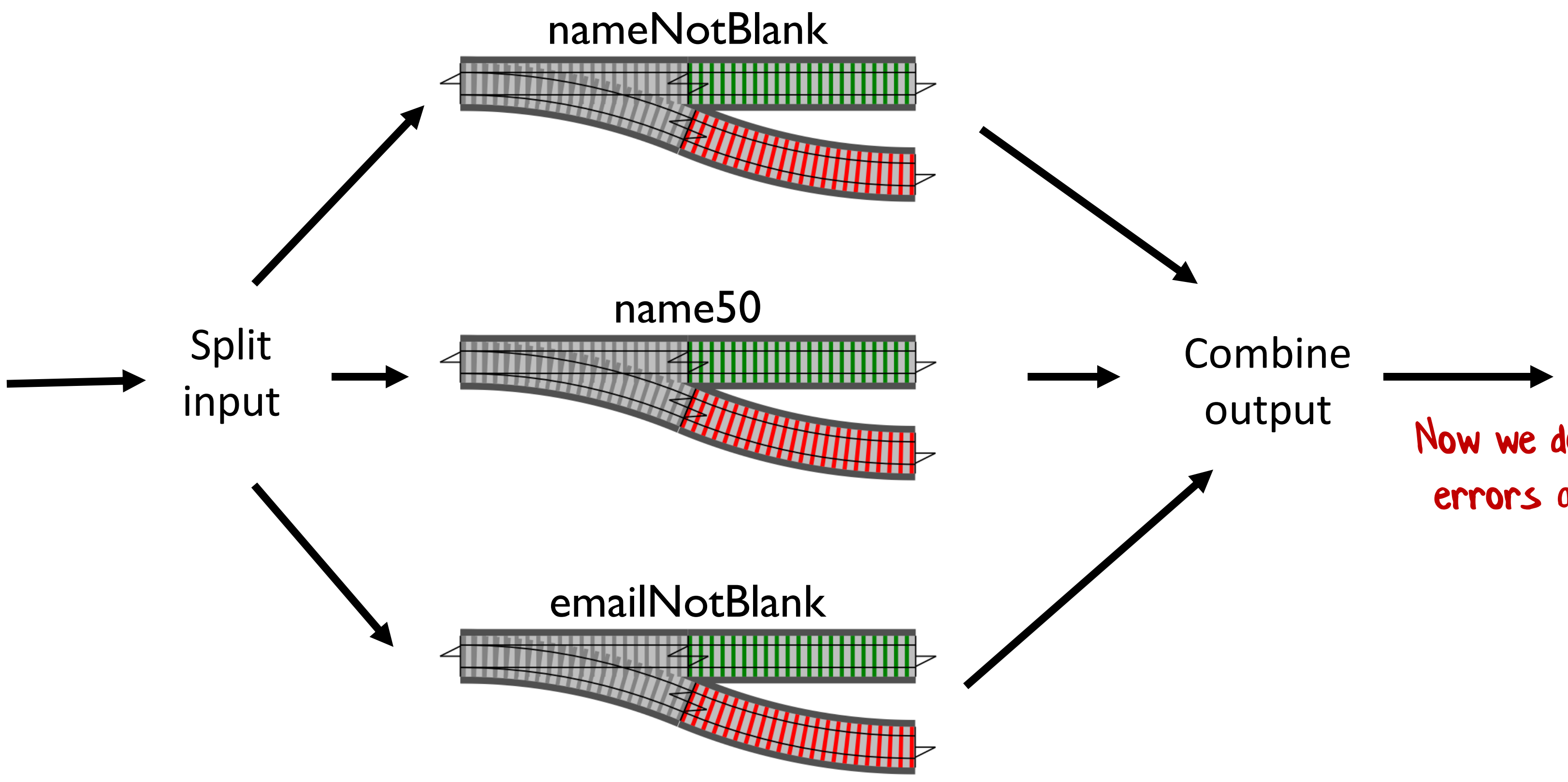
Parallel validation



Problem: Validation done in series.
So only one error at a time is returned

It would be nice to return all
validation errors at once.

Parallel validation



Now we do get all errors at once!

... But how to combine?

How does it work?

- A bunch of functions that return a ValidationType
- A constructor
- Use <!> and <*>

Demo and exercise 04