Practical Session Types

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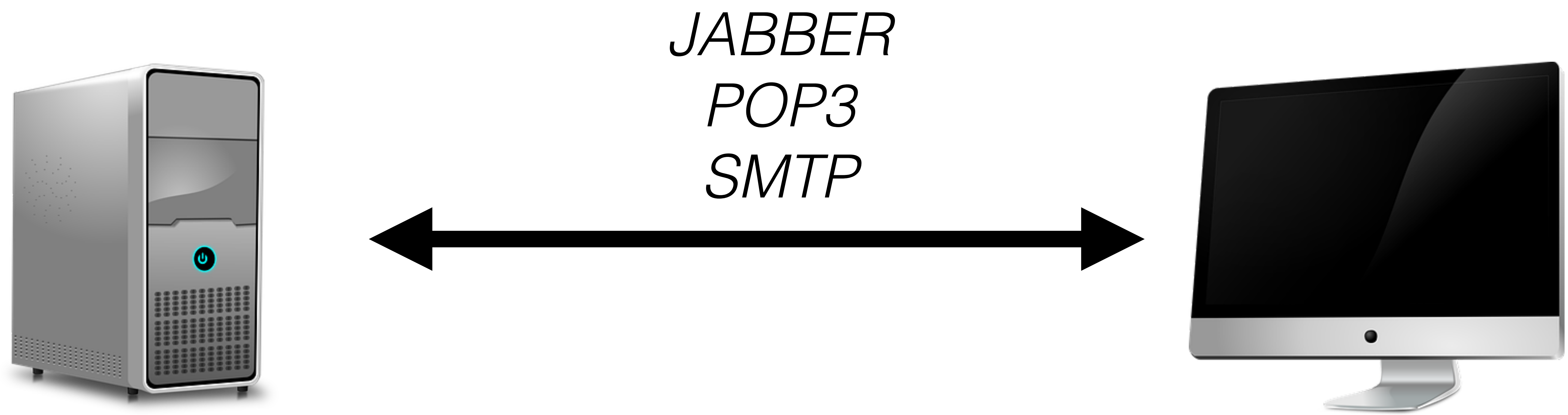
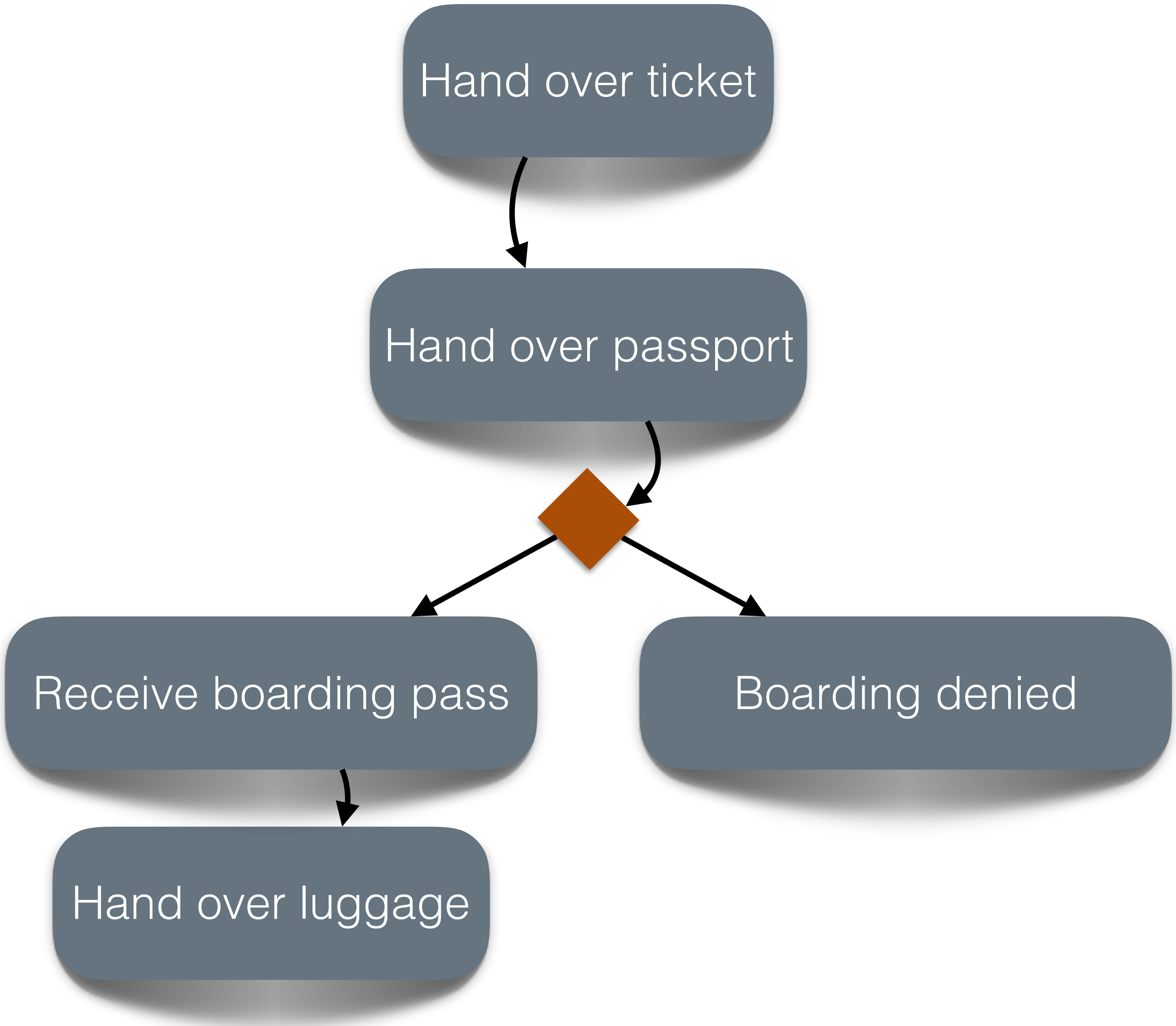
Session Types

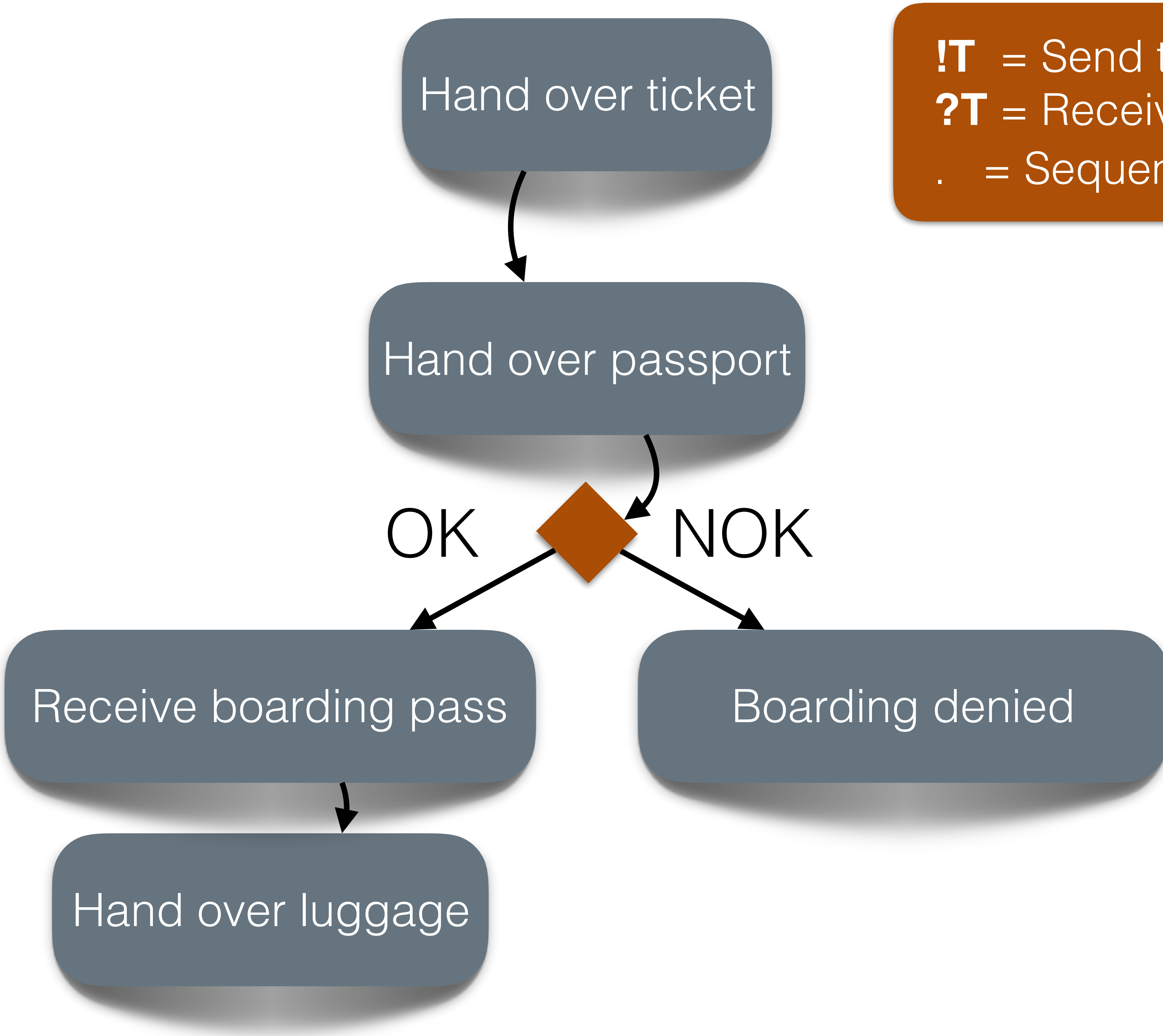


State of the art

Calculi	Programming Languages
Functional Calculi	Haskell, Scala, OCaml, Links, Sill, C, Erlang, Go, Rust, Java
π-calculus	
Object-Oriented	

Running Example + Session Types in a Nutshell


Hand over ticket
Hand over passport
Receive boarding pass
Boarding denied
Hand over luggage



!T = Send type T
?T = Receive type T
. = Sequence

```
!Ticket.!Passport.&<OK : ?BoardingPass.!Luggage.End,
                    NOK: ?String.End
>
```

Duality

```
!Ticket.!Passport.&<OK : ?BoardingPass.!Luggage.End,
                    NOK: ?String.End                          >
```

!T → ?T

?T → !T

&<..> → ⊕<..>

⊕ <..> → &<..>

```
?Ticket.?Passport.⊕<OK : !BoardingPass.?Luggage.End,
                    NOK: !String.End                          >
```

Modularity is difficult

Types

Logic

```
sestyp Checkin = ⊕<NORMAL: !Ticket.!Passport,
                   FAST  : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                NOK: End                         >

sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass airport = return (receive airport)

sendLuggage airport = let luggage = grabFromTrunk in send luggage airport ;

checkin airport = select NORMAL airport ;
                        sendTicket ; sendPassport ;
                  case airport
                    OK  = let boardingpass = getBoardingPass airport
                          in
                            sendLuggage airport ;
                            close airport
                    NOK = let error = receive airport
                          in
                            close airport ;
                            error (format “Go back home: %s” error)
```

Refactor

```
sestyp Checkin = ⊕<NORMAL: !Ticket.!Passport,
                   FAST  : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                NOK: End                         >

sendTicket :: [ß:Checkin] Chan ß
              ->
              [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport :: [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
                ->
                [ß:&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass :: [ß:?BoardingPass.!Luggage.End] Chan ß
                   ->
                   [ß:!Luggage.End] Chan ß
getBoardingPass airport = return (receive airport)

sendLuggage :: [ß:!Luggage.End] Chan ß -> [ß:End] Chan ß
sendLuggage airport = let luggage = grabFromTrunk in send luggage airport ;

checkin :: [ß:Checkin] Chan ß -> [ß:/] ()
checkin airport = select NORMAL airport ;
                        sendTicket ; sendPassport ;
                  case airport
                    OK  = let boardingpass = getBoardingPass airport
                          in
                            sendLuggage airport ;
                            close airport
                    NOK = let error = receive airport
                          in
                            close airport ;
                            error (format “Go back home: %s” error)
```

Type information explodes

Improving modularity at the type level in session type programs

- Polymorphism for full session types
- Pattern Matching
- Session types in System F

Session Types in practice

A FUNCTION WORKING ON TYPES

Session Typed Function

```
checkin :: [ß:S] Chan ß -> [ß:S’] Bool
```

Syntax of prototype implementation

A SAMPLE PROGRAM

```
session Checkin = !Ticket.!Passport.&<OK : ?BoardingPass.!Luggage.End,
                                       NOK: End                       >

checkin :: [ß:Checkin] Chan ß -> [ß:End] Chan ß
checkin airport = let ticket   = grabTicket
                      passport = grabPassport
                      luggage  = grabFromTrunk
                  in
                    send ticket airport ;
                    send passport airport ;
                    case airport
                       OK  = let boardingpass = receive airport
                             in
                               send luggage airport ;
                               close airport
                       NOK = let err = receive airport
                             in
                               close airport ;
                               error (format “Go back home: %s” err)
```

A SAMPLE PROGRAM

```
session Checkin = !Ticket.!Passport.&<OK : ?BoardingPass.!Luggage.End,
                                         NOK: End                       >

checkin :: [ß:Checkin] Chan ß -> [ß:End] Chan ß
checkin airport = let ticket   = grabTicket
                      passport = grabPassport
                      luggage  = grabFromTrunk
                  in
                    send ticket airport ;
                    send passport airport ;
                    case airport
                       OK  = let boardingpass = receive airport
                             in
                               send luggage airport ;
                               close airport
                       NOK = let err = receive airport
                             in
                               close airport ;
                               error (format “Go back home: %s” err)
```

A SAMPLE PROGRAM

```
session Checkin = !Ticket.!Passport.&<OK : ?BoardingPass.!Luggage.End,
                                        NOK: End                        >

checkin :: [ß:Checkin] Chan ß -> [ß:End] Chan ß
checkin airport = let ticket   = grabTicket
                      passport = grabPassport
                      luggage  = grabFromTrunk
                  in
                    send ticket airport ;
                    send passport airport ;
                    case airport
                       OK  = let boardingpass = receive airport
                             in
                               send luggage airport ;
                               close airport
                       NOK = let err = receive airport
                             in
                               close airport ;
                               error (format “Go back home: %s” err)
```

=

```
sendTicket :: [ß:Checkin] Chan ß
              ->
              [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK:
End >] Chan ß
sendTicket airport = let ticket = grabTicket in send ticket airport
```

Modularity is difficult

Types

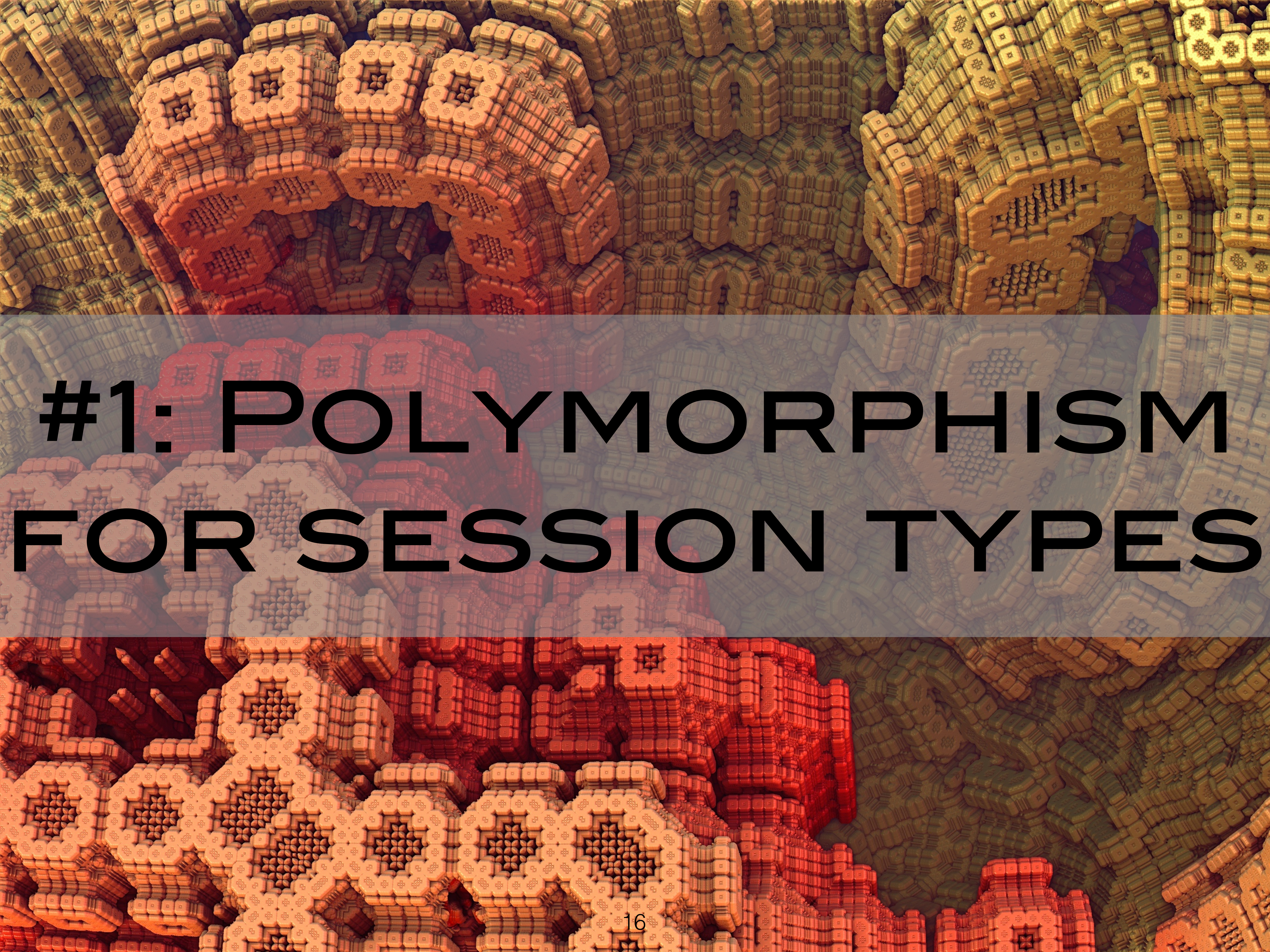
Logic

```
sestyp Checkin = ⊕<NORMAL: !Ticket.!Passport,
                    FAST  : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                 NOK: End                       >

sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass airport = return (receive airport)

sendLuggage airport = let luggage = grabFromTrunk in send luggage airport ;

checkin airport = select NORMAL airport ;
                        sendTicket ; sendPassport ;
                  case airport
                    OK  = let boardingpass = getBoardingPass airport
                          in
                            sendLuggage airport ;
                            close airport
                    NOK = let error = receive airport
                          in
                            close airport ;
                            error (format “Go back home: %s” error)
```

Refactor

```
sestyp Checkin = ⊕<NORMAL: !Ticket.!Passport,
                    FAST  : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                 NOK: End                       >

sendTicket :: [ß:Checkin] Chan ß
              ->
              [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport :: [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
                ->
                [ß:&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass :: [ß:?BoardingPass.!Luggage.End] Chan ß
                   ->
                   [ß:!Luggage.End] Chan ß
getBoardingPass airport = return (receive airport)

sendLuggage :: [ß:!Luggage.End] Chan ß -> [ß:End] Chan ß
sendLuggage airport = let luggage = grabFromTrunk in send luggage airport ;

checkin :: [ß:Checkin] Chan ß -> [ß:/] ()
checkin airport = select NORMAL airport ;
                        sendTicket ; sendPassport ;
                  case airport
                    OK  = let boardingpass = getBoardingPass airport
                          in
                            sendLuggage airport ;
                            close airport
                    NOK = let error = receive airport
                          in
                            close airport ;
                            error (format “Go back home: %s” error)
```

Type information explodes

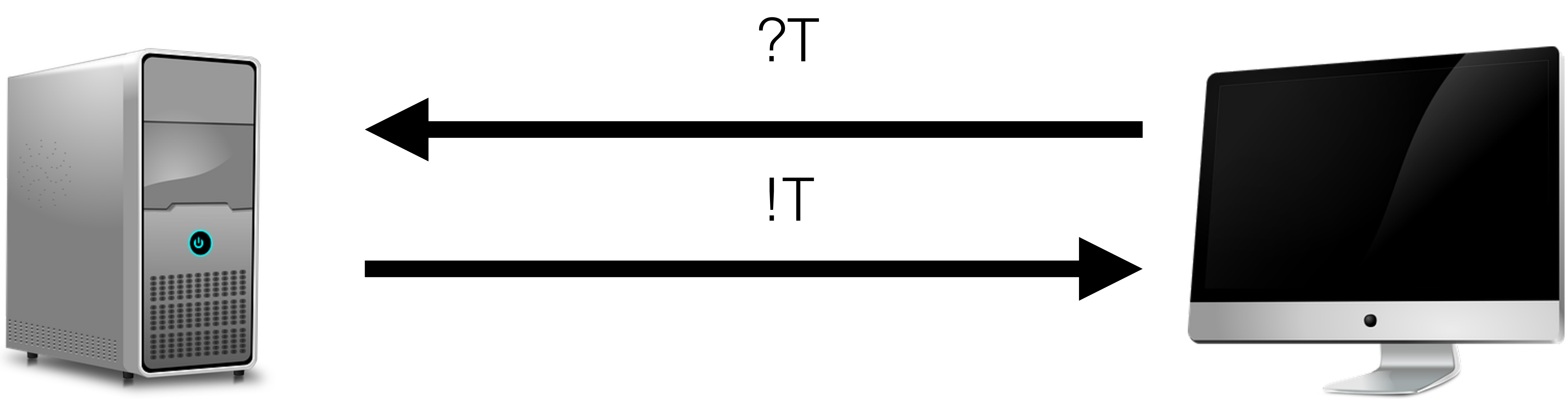


#1: Polymorphism for session types

Polymorphism

Receive and send back

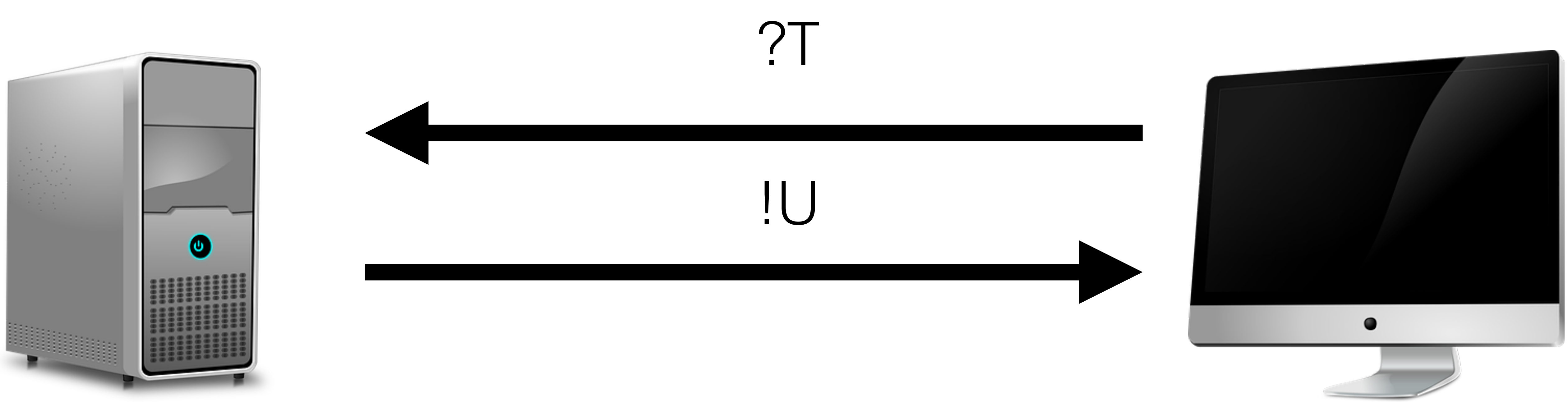
```
sendBack :: ForAll T . [ß: ?T.!T.End] Chan ß -> [ß:End]()
```



POLYMORPHISM

Apply f to the received value and send it back

```
sendBack :: ForAll T,U . [ß: ?T.!U.End] Chan ß -> (T -> U) -> [ß:End]()
sendBack chn f = let incoming = receive chn
                     outgoing = f incoming
                 in
                   send outgoing chn
```



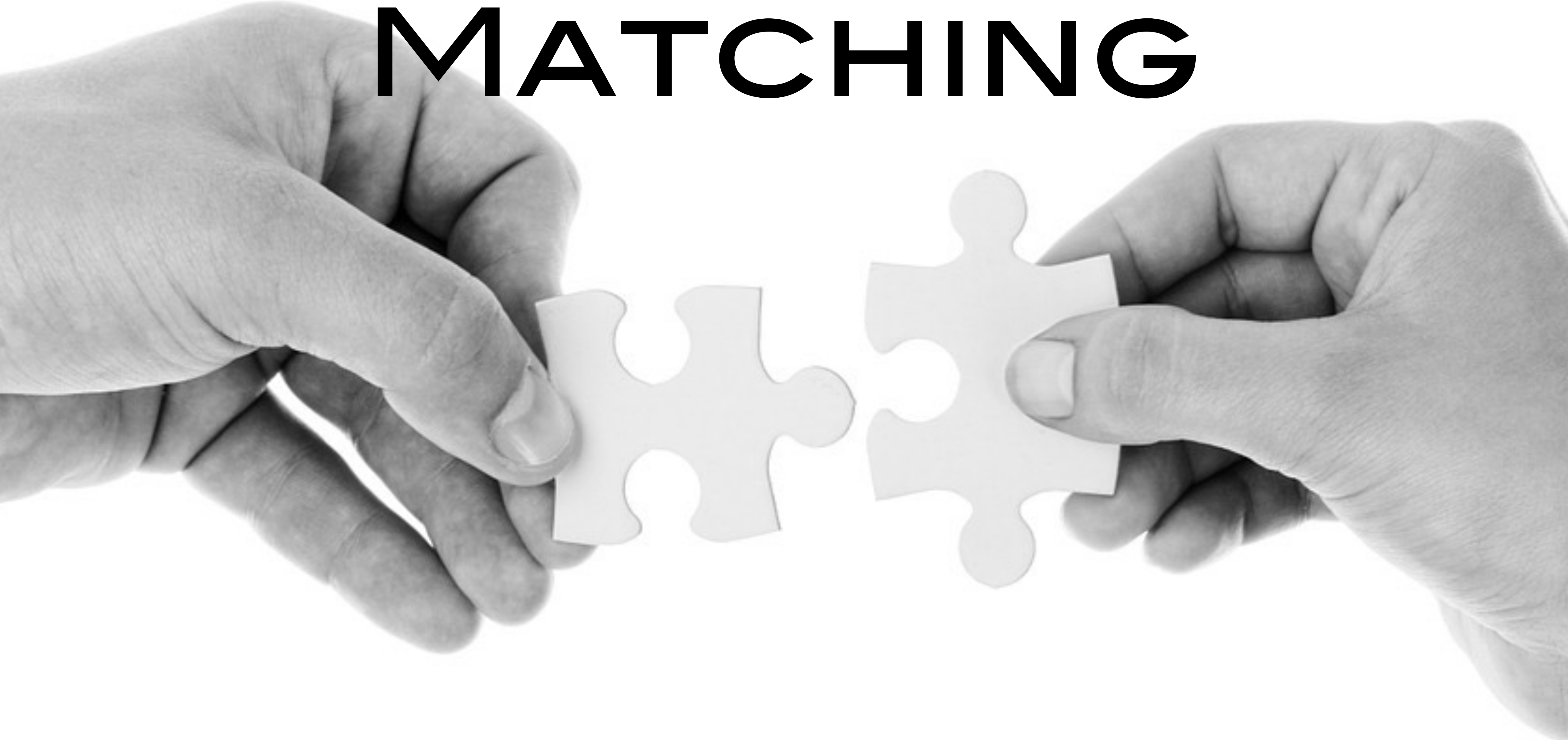
POLYMORPHISM

```
session Checkin = ⊕<NORMAL: !Ticket.!Passport,
                    FAST   : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                   NOK: End                          >

customsHandbag :: [ß:?HandBag.⊕<OK: !HandBag, ERR: !Reason>.End] Chan ß -> [ß:End] ()
customsHandbag conveyorbelt = let handbag = receive conveyorbelt
                              in
                                if (containsLiquids? handbag)
                                  then select NOK conveyorbelt
                                       send “Not allowed!”
                                  else send handbag conveyorbelt

customsLuggage :: [ß:?Luggage.⊕<OK: !Luggage, ERR: !Reason>.End] Chan ß -> [ß:End] ()
customsLuggage conveyorbelt = let luggage = receive conveyorbelt
                              in
                                if (containsDrugs? handbag)
                                  then select NOK conveyorbelt
                                       send “Not allowed!”
                                  else send handbag conveyorbelt
```

Polymorphism for Session Types

```
session Checkin = ⊕<NORMAL: !Ticket.!Passport,
                    FAST  : !Barcode          >.&<OK : ?BoardingPass.!Luggage.End,
                                                  NOK: End                      >

checkWith :: [ß:?T.⊕<OK: !T, ERR: !Reason>.End] Chan ß -> (T -> Bool) -> [ß:End] ()
checkWith conveyorbelt f = let t = receive conveyorbelt
                           in
                             if (f t)
                               then select ERR conveyorbelt
                                    send “Not allowed!”
                                    else send t conveyorbelt

customsHandbag :: [ß:?HandBag.⊕<OK: !HandBag.End, ERR: !Reason>.End] Chan ß -> [ß:End] ()
customsHandbag conveyorbelt = checkWith conveyorbelt containsLiquids?

customsLuggage :: [ß:?Luggage.⊕<OK: !Luggage, ERR: !Reason>.End] Chan ß -> [ß:End] ()
customsLuggage conveyorbelt = checkWith conveyorbelt containsDrugs?
```

#2: Pattern Matching



Enforce Structural constraints

“As long as the session type wants me to send an Int”

```
f :: [ß: S.!Int.U] Chan ß -> [ß:U] ()
```

“As long as the channel offers these two choices”

```
h :: [ß: &<CH1: S, CH2: T>.U] Chan ß -> [ß:U] ()
```

A sample program

```
sendTicket :: [ß:Checkin] Chan ß
              ->
              [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport :: [ß:!Passport.&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
                ->
                [ß:&<OK : ?BoardingPass.!Luggage.End, NOK: End >] Chan ß
sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass :: [ß:?BoardingPass.!Luggage.End] Chan ß
                   ->
                   [ß:!Luggage.End] Chan ß
getBoardingPass airport = return (receive airport)
```

A BETTER SAMPLE PROGRAM

```
[ß:⊕<FAST: S, NORMAL: S’>.S”]
```

```
selectFastTrack :: [ß:⊕<FAST: S, NORMAL: S’>.S”] Chan ß -> [ß:S.S”] Chan ß
selectFastTrack airport = select FAST airport

sendTicket :: [ß:!Ticket.S] Chan ß -> [ß:S] Chan ß
sendTicket airport = let ticket = grabTicket in send ticket airport

sendPassport :: [ß:!Passport.S] Chan ß -> [ß:S] Chan ß
sendPassport airport = let passport = grabPassport in send passport airport

getBoardingPass :: [ß:?BoardingPass.S] Chan ß -> [ß:S] BoardingPass
getBoardingPass airport = return (receive airport)
```

```
[ß:?BoardingPass.S]
```

Thank you!

- Help session types transform with program
- Reduce type overhead
- Proof of Concept implementation
    - Polymorphism for full session types
    - Pattern matching (Structural Constraints)
    - System F with session types
- All images taken from pixabay.com