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1 Task 1

1.1 Repeat until

$$\frac{\Gamma \vdash e : \text{Boolean} \quad \Gamma \vdash \bar{c}}{\Gamma \vdash \text{repeat } \bar{c} \text{ until } e}$$

1.2 Character literal

$$\Gamma \vdash ch : \text{Character}$$

1.3 If-else extended

$$\frac{\begin{array}{l} \Gamma \vdash e_1 : \text{Boolean} \quad \Gamma \vdash \bar{e}_2 : \text{Boolean} \\ \Gamma \vdash \bar{c}_1 \quad \Gamma \vdash \bar{c}_2 \quad \Gamma \vdash \bar{c}_3 \end{array}}{\Gamma \vdash \text{if } e_1 \text{ then } \bar{c}_1 \text{ elsif } \bar{e}_2 \text{ then } \bar{c}_2 \text{ else } \bar{c}_3}$$

1.4 Conditional expression

$$\frac{\begin{array}{l} \Gamma \vdash e_1 : \text{Boolean} \quad \Gamma \vdash e_2 : T \\ \Gamma \vdash e_3 : T \quad \neg \text{leftype}(T) \end{array}}{\Gamma \vdash e_1 ? e_2 : e_3}$$

2 Task 2

2.1 Repeat until

2.1.1 MTIR

Update the MiniTriangle Internal Representation inside, so we can stored typed version

```
-- | Repeat until
| CmdRepeat {
  crCond    :: Expression,      -- ^ Loop-condition
  crBody    :: Command,        -- ^ Loop-body
  cmdSrcPos :: SrcPos
}
```

2.1.2 TypeChecker

Add a pattern match for type checking AST CmdRepeat data type

```
-- T-REPEAT
chkCmd env (A.CmdRepeat {A.crCond = e, A.crBody = c, A.cmdSrcPos = sp}) = do
  e' <- chkTpExp env e Boolean      -- env |- e : Boolean
  c' <- chkCmd env c                -- env |- c
  return (CmdRepeat {crCond = e', crBody = c', cmdSrcPos = sp})
```

2.1.3 PPMTIR

Now need a way to print the typed repeat command. We do this by adding a `CmdRepeat` pattern match to `ppCommand`

```
ppCommand n (CmdRepeat {crCond = e, crBody = c, cmdSrcPos = sp}) =
  indent n . showString "CmdRepeat" . spc . ppSrcPos sp . nl
  . ppCommand (n+1) c
  . ppExpression (n+1) e
```

2.2 Character literal

2.2.1 Type

Firstly we add `Character` to `Type` data type

```
| Character      -- ^ The Character type
```

Next inside `instance Eq Type` where we add an equality operator pattern for it.

```
Character == Character = True
```

Finally, we add `Character` pattern match to `instance Show Type` where

```
showsPrec _ Character = showString "Character"
```

2.2.2 TypeChecker

We add a `ExpLitChar` pattern match to `infTpExp`. The only thing we do here is convert the character value to `MTChar` and transform $AST \rightarrow MTIR$

```
-- T-CHAR
infTpExp env e@(A.ExpLitChr {A.elcVal = c, A.expSrcPos = sp}) = do
  c' <- toMTChr c sp
  return (Character,
          ExpLitChr {elcVal = c', expType = Character, expSrcPos = sp})
```

2.2.3 MTStdEnv

We also need to update our standard environment to contain characters. Do this by updating first list argument in `mtStdEnv` function

```
mtStdEnv :: Env
mtStdEnv =
  mkTopLvlEnv
    [("Boolean", Boolean),
     ("Integer", Integer),
     ("Character", Character)]
  [("false", Boolean, ESVBool False),
   ("true", Boolean, ESVBool True),
   ("minint", Integer, ESVInt (minBound :: MTInt)),
   ("maxint", Integer, ESVInt (maxBound :: MTInt)),
   ("+", Arr [Integer, Integer] Integer, ESVLbl "add"),
   ("-", Arr [Integer, Integer] Integer, ESVLbl "sub"),
   ("*", Arr [Integer, Integer] Integer, ESVLbl "mul"),
   ("/", Arr [Integer, Integer] Integer, ESVLbl "div"),
   ("^", Arr [Integer, Integer] Integer, ESVLbl "pow"),
   ("neg", Arr [Integer] Integer, ESVLbl "neg"),
  ("<", Arr [Integer, Integer] Boolean, ESVLbl "lt"),
  ("<=", Arr [Integer, Integer] Boolean, ESVLbl "le"),
   ("==", Arr [Integer, Integer] Boolean, ESVLbl "eq"),
```

```

("!=",      Arr [Integer, Integer] Boolean, ESVLbl "ne"),
(">=",      Arr [Integer, Integer] Boolean, ESVLbl "ge"),
(">",       Arr [Integer, Integer] Boolean, ESVLbl "gt"),
("&&",      Arr [Boolean, Boolean] Boolean, ESVLbl "and"),
("||",      Arr [Boolean, Boolean] Boolean, ESVLbl "or"),
("!",       Arr [Boolean] Boolean,          ESVLbl "not"),
("getint",  Arr [Integer] Void,             ESVLbl "getint"),
("putint",  Arr [Integer] Void,             ESVLbl "putint"),
("skip",    Arr [] Void,                   ESVLbl "skip")]

```

2.3 If-else extended

2.3.1 MTIR

Firstly, we update the internal representation to allow multiple *elsif* and optional *else* branches. Do this by modifying `CmdIf` inside `Command` data type.

```

-- | Conditional command
| CmdIf {
    ciCondThens :: [(Expression,
                          Command)], -- ^ Conditional branches
    ciMbElse     :: Maybe Command, -- ^ Optional else-branch
    cmdSrcPos    :: SrcPos
}

```

2.3.2 PPMTIR

Now we need to update the pretty print function, so the new syntax can be seen

```

ppCommand n (CmdIf {ciCondThens = ecs, ciMbElse = mc, cmdSrcPos = sp}) =
    indent n . showString "CmdIf" . spc . ppSrcPos sp . nl
    . ppSeq (n+1) (\n (e,c) -> ppExpression n e . ppCommand n c) ecs
    . ppOpt (n+1) ppCommand mc

```

2.3.3 TypeChecker

Next we have to update the command type checking. Do this by updating `chkCmd` function with:

```

-- T-IF
chkCmd env (A.CmdIf {A.ciCondThens = ifs, A.ciMbElse = mbElse,
                    A.cmdSrcPos=sp}) = do
    ifs' <- mapM chkThen ifs
    mbElse' <- case mbElse of
        Nothing -> return Nothing
        Just c -> fmap Just $ chkCmd env c
    return (CmdIf {ciCondThens = ifs', ciMbElse = mbElse', cmdSrcPos = sp})
    where
        chkThen (e, c) = do
            e' <- chkTpExp env e Boolean
            c' <- chkCmd env c
            return (e', c')

```

In the first step we have to go through the list of our if branches checking each one. We use `mapM` here in order to make sure list is wrapped in a single monad, rather than having a list of monads. Next we check the optional else branch. To do this properly, we need to make sure that it always returns `D Maybe` type. If no branch, we just use return function to wrap our `Maybe` type. If there is a command, we run a check and then map inner contents with a `Just` type

2.4 Conditional expression

2.4.1 MTIR

Firstly add a new data type to `Expresion`.

```
-- | Conditional expression
| ExpCond {
    ecCond    :: Expression,      -- ^ Condition
    ecTrue    :: Expression,      -- ^ Value if condition true
    ecFalse   :: Expression,      -- ^ Value if condition false
    expType   :: Type,           -- ^ Type
    expSrcPos :: SrcPos
}
```

2.4.2 PPMTIR

Next we add a way to print the expression to the screen

```
ppExpression n (ExpCond {ecCond = c, ecTrue = et, ecFalse = ef, expType = t, expSrcPos = sp}) =
    indent n . showString "ExpCond" . spc . ppSrcPos sp . nl
    . ppExpression (n+1) c
    . ppExpression (n+1) et
    . ppExpression (n+1) ef
    . indent n . showString ": " . shows t . nl
```

2.4.3 TypeChecker

Now we can add a typechecking pattern to `infTpExp`

```
-- T-COND
infTpExp env (A.ExpCond { A.ecCond = c, A.ecTrue = l, A.ecFalse = r, A.expSrcPos = sp }) = do
    c' <- chkTpExp env c Boolean
    (tl, l') <- infNonRefTpExp env l
    (tr, r') <- infNonRefTpExp env r
    require (tl == tr) sp $ errMsg tl tr
    -- Make sure both types are same and not reference
    return (tl, ExpCond { ecCond = c', ecTrue = l', ecFalse = r', expType = tl, expSrcPos = sp })
    where
        errMsg tl tr = "Expected: " ++ (show tl) ++ " and " ++ (show tr) ++ " types to match"
```

We make sure that both types are the same as well as both non-references. Because both are the same we just assign left expression type as the main expression type.