A (Not So Gentle) Introduction To ATS

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Outline

Hello world

- Minimal

```
implement main0 () = println! "hello world!"
```

Swap

- A slightly non-standard swap

```
void swap(void *i, void *j, size_t size) {
  void* tmp = malloc(size);
  memcpy(tmp, j, size);
  memcpy(j, i, size);
  memcpy(i, tmp, size);
  free(tmp);
}
```

Swap

- A slightly non-standard swap

```
void swap(void *i, void *j, size_t size) {
  void* tmp = malloc(size);




}
```

Swap

- A slightly non-standard swap

```
void swap(void *i, void *j, size_t size) {
  void* tmp = malloc(size);
  memcpy(tmp, j, size);
  memcpy(j, i, size);
  memcpy(i, tmp, size);

}
```

Swap

- A slightly non-standard swap

```
void swap(void *i, void *j, size_t size) {
  void* tmp = malloc(size);
  memcpy(tmp, j, size);
  memcpy(j, i, size);
  memcpy(i, tmp, size);
  free(tmp);
}
```

Swap

- A slightly non-standard swap

```
%{
  #include <stdio.h>
  void swap(void *i, void *j, size_t size) {
    ...
  }
%}
```

Swap

- A slightly non-standard swap

```
%{
  #include <stdio.h>
  void swap(void *i, void *j, size_t size) {
    ...
  }
%}
extern fun swap (i:ptr, j:ptr, s:size_t) : void = "ext#swap"
```

Swap

- A slightly non-standard swap

```
%{
  #include <stdio.h>
  void swap(void *i, void *j, size_t size) {
    ...
  }
%}
extern fun swap (i:ptr, j:ptr, s:size_t) : void = "ext#swap"
extern fun malloc(s:size_t):ptr = "ext#malloc"
```

Swap

- Runner

```
implement main0 () =
  let
      val i = malloc(sizeof<int>)
      val j = malloc(sizeof<double>)
      val _ = swap(i,j,sizeof<double>)
  in
      ()
  end
```

Swap

- Runner

```
implement main0 () =
  let
      val i = malloc(sizeof<int>) // all good


  in

  end
```

Swap

- Runner

```
implement main0 () =
  let
      val i = malloc(sizeof<int>)
      val j = malloc(sizeof<double>) // uh oh!

  in

  end
```

Swap

- Runner

```
implement main0 () =
  let
      val i = malloc(sizeof<int>)
      val j = malloc(sizeof<double>)
      val _ = swap(i,j,sizeof<double>) // oh noes!
  in

  end
```

Swap

- Runner

```
implement main0 () =
  let
      val i = malloc(sizeof<int>)
      val j = malloc(sizeof<double>)
      val _ = swap(i,j,sizeof<double>)
  in
      () // free as in leak
  end
```

Swap

- Safe swap

```
extern fun swap (i:ptr, j:ptr, s:size_t) : void = "ext#swap"
```

- Safe swap

```
extern fun swap                               : void = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap                              :        = "ext#swap"
```

- Safe swap

```
extern fun swap



                        = "ext#swap"
```

- Safe swap

```
extern fun swap
  {a : t@ype}



                                = "ext#swap"
```

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr |            }


                            = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}


                            = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}


                          = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (                 i : ptr l1                         ):
                        = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (                 i : ptr l1, j : ptr l2                 ):
                        = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (                 i : ptr l1, j : ptr l2, s: sizeof_t a):
                       = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (                  | i : ptr l1, j : ptr l2, s: sizeof_t a):
                          = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1           | i : ptr l1, j : ptr l2, s: sizeof_t a):
                         = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
                          = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
    (                           ) = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
    (                    void) = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
    (                | void) = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
    (a @ l1           | void) = "ext#swap"
```

Swap

- Safe swap

```
extern fun swap
  {a : t@ype}
  {l1: addr | l1 > null}
  {l2: addr | l2 > null}
  (a @ l1 , a @ l2 | i : ptr l1, j : ptr l2, s: sizeof_t a):
    (a @ l1, a @ l2 | void) = "ext#swap"
```

Swap

- Safe swap

```
extern fun malloc(s:size_t):ptr = "ext#malloc"
```

- Safe swap

```
extern fun malloc


   = "ext#malloc"
```

- Safe swap

```
extern fun malloc
        {a:t@ype}


    = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
       {a:t@ype}
       (s:sizeof_t a):

   = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
       {a:t@ype}
       (s:sizeof_t a):
                            (         ptr l)
   = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
       {a:t@ype}
       (s:sizeof_t a):
                            (a? @ l | ptr l)
   = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
        {a:t@ype}
        (s:sizeof_t a):
        [                    ] (a? @ l | ptr l)
   = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
       {a:t@ype}
       (s:sizeof_t a):
       [l:addr          ] (a? @ l | ptr l)
   = "ext#malloc"
```

Swap

- Safe swap

```
extern fun malloc
       {a:t@ype}
       (s:sizeof_t a):
       [l:addr | l > null] (a? @ l | ptr l)
  = "ext#malloc"
```

Swap

- Safe swap

```
implement main0 () = let
  val (      i) = malloc (sizeof<int>)




in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (    | i) = malloc (sizeof<int>)




in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)




in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)




in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val           = ptr_set(      i, 1)


in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val           = ptr_set(pfi | i, 1)


in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)

in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val                 = swap(              i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val                = swap(                | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val              = swap(pfi1        | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val                  = swap(pfi1, pfj2 | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val (            ()) = swap(pfi1, pfj2 | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val (pfi2     | _) = swap(pfi1, pfj1 | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val (pfi2,pfj2 | _) = swap(pfi1, pfj1 | i, j, sizeof<int>)
in


end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val (pfi2,pfj2| _) = swap(pfi1, pfj2 | i, j, sizeof<int>)
in
  free(pfi2 | i);

end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi | i) = malloc (sizeof<int>)
  val (pfj | j) = malloc (sizeof<int>)
  val (pfi1 | _) = ptr_set(pfi | i, 1)
  val (pfj1 | _) = ptr_set(pfj | j, 2)
  val (pfi2,pfj2| _) = swap(pfi1, pfj1 | i, j, sizeof<int>)
in
  free(pfi2 | i);
  free(pfj2 | j);
end
```

Swap

- Safe swap

```
implement main0 () = let
  val (pfi    ) = malloc
       ~~~
  val (pfi1 | _) = ptr_set(pfi |      )
       ~~~~              ~~~

in


end
```

Swap

- Safe swap

```
implement main0 () = let


  val (pfi1 | _) =
       ~~~~
  val (pfi2,    | _) == swap(pfi1,        |                  )
in     ~~~~                        ~~~~



end
```

Swap

- Safe swap

```
implement main0 () = let



  val (pfi2,    | _) =
in      ^^^^
  free(pfi2 | );
        ^^^^
end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of
      | 1 => acc
      | i when i > 1 => loop(acc * i, i - 1)

  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial


  let
    fun loop




  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }

  let
    fun loop




  in
    loop(1.0, i)
  end
```

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop



  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }




  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }

        (acc : double, i : int (n)) : double =




  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =




  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of



  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of
      | 1 => acc
      |

  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of
      | 1 => acc
      | i

  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of
      | 1 => acc
      | i when i > 1

  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial
    { n : int | n >= 1 }
    (i : int n) : double =
  let
    fun loop
        { n : int | n >= 1 }
        .<n>.
        (acc : double, i : int (n)) : double =
      case- i of
      | 1 => acc
      | i when i > 1 => loop(acc * i, i - 1)

  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial


  let
    fun loop
        { n : int | n >= 1 } <---



      case- i of
      |
      | i when i > 1 => loop(acc * i, i - 1)
          ~~~~~~~~~~
  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial


  let
    fun loop
        { n : int | n >= 1 } <---



      case- i of
      |
      | i when i > 1 => loop(acc * i, i - 1)
                                    ^^^^^
  in
    loop(1.0, i)
  end
```

Factorial

- Factorial

```
fun factorial


  let
    fun loop


        .<n>. <---


      case- i of
      |
      | i when i > 1 => loop(acc * i, i + 1)
                                   ^^^^^
  in
    loop(1.0, i)
  end
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l, array_v (a, l+sizeof a, n-1))
```

- ADT describing an array of pointers

```
dataview array_v
(



) =
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(



) =
    array_v_nil
  |
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(




) =
    array_v_nil
  | array_v_cons
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,


) =
    array_v_nil
  | array_v_cons
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,

) =
    array_v_nil
  | array_v_cons
```

Dataviewtype

- ADT describing an array of pointers

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  a:t@ype,
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  n : int
) =
    array_v_nil
  | array_v_cons
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n)
```

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l,                                )
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l, array_v (                    ))
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l, array_v (a,                  ))
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l, array_v (a, l+sizeof a,    ))
```

Dataviewtype

- ADT describing an array of pointers

```
dataview array_v
(
  a:t@ype,
  l: addr,
  n : int
) =
    array_v_nil  (a, l, 0)
  | array_v_cons (a, l, n) of
      (a @ l, array_v (a, l+sizeof a, n-1))
```