NLFFI
A new SML/NJ Foreign-Function Interface

(for SML/NJ version 110.46 and later)

User Manual

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The `ml-nlffigen` tool generates one ML structure for each exported C definition. In particular, there is one structure per external variable, function, `typedef`, `struct`, `union`, and `enum`. Each generated ML structure contains the ML type and values necessary to manipulate the corresponding C item.

3.1 External variables

An external C variable v of type t_C is represented by an ML structure `G_`v. This structure always contains a type `t` encoding t_C and a value `obj'` providing ("light-weight") access to the memory location that v stands for in C. If t_C is *complete*, then `G_`v will also contain a value `obj` (the "heavy-weight" equivalent of `obj'`) as well as value `typ` holding run-time type information corresponding to t_C (and `t`).

Details

`type t` is the type to be substituted for τ in `(`τ`,` ζ`) C.obj` to yield the correct type for ML values representing C memory objects of type t_C (i.e., v's type). (This assumes a properly instantiated ζ based on whether or not the corresponding object was declared `const`.)

!`val typ` is the run-time type information corresponding to type `t`. The ML type of `typ` is `t C.T.typ`. This value is not present if t_C is *incomplete*.

!`val obj` is a function that returns the ML-side representative of the C object (i.e., the memory location) referred to by v. Depending on whether or not v was declared `const`, the type of `obj` is either `unit -> (t, C.ro) C.obj` or `unit -> (t, C.rw) C.obj`. The result of `obj()` is "heavy-weight," i.e., it implicitly carries run-time type information. This value is not present if t_C is *incomplete*.

`val obj'` is analogous to `val obj`, the only difference being that its result is "light-weight," i.e., without run-time type information. The type of `val obj'` is either `unit -> (t, C.ro) C.obj` or `unit -> (t, C.rw) C.obj`.

(Elements that are subject to omission due to incompleteness of types are marked with an exclamation mark(!).)

Examples

C declaration	signature of ML-side representation

`extern int i;`	`structure G_i : sig`
	`    type t    = C.sint`
	`    val typ   : t C.T.typ`
	`    val obj   : unit -> (t, C.rw) C.obj`
	`    val obj'  : unit -> (t, C.rw) C.obj'`
	`end`

`extern const double d;`	`structure G_d : sig`
	`    type t    = C.double`
	`    val typ   : t C.T.typ`
	`    val obj   : unit -> (t, C.ro) C.obj`
	`    val obj'  : unit -> (t, C.ro) C.obj'`
	`end`

`extern struct str s1;`
`/* str complete */`
	`structure G_s1 : sig`
	`    type t    = (S_str.tag C.su, rw) C.obj C.ptr`
	`    val typ   : t C.T.typ`
	`    val obj   : unit -> (t, C.rw) C.obj`
	`    val obj'  : unit -> (t, C.rw) C.obj'`
	`end`

`extern struct istr s2;`
`/* istr incomplete */`
	`structure G_s2 : sig`
	`    type t    = (ST_istr.tag C.su, rw) C.obj C.ptr`
	`    val obj'  : unit -> (t, C.rw) C.obj'`
	`end`

3.2 Functions

An external C function *f* is represented by an ML structure `F_`*f*. Each such structure always contains at last three values: `typ`, `fptr`, and `f'`. Variable `typ` holds run-time type information regarding function pointers that share *f*'s prototype. The most important part of this information is the code that implements native C calling conventions for these functions. Variable `fptr` provides access to a C pointer to *f*. And `f'` is an ML function that dispatches a call of *f* (through `fptr`), using "light-weight" types for arguments and results. If the result type of *f* is *complete*, then `F_`*f* will also contain a function `f`, using "heavy-weight" argument- and result-types.

Details

`val typ` holds run-time type information for pointers to functions of the same prototype. The ML type of `typ` is `(`A `->` B`) C.fptr C.T.typ` where A and B are types encoding *f*'s argument list and result type, respectively. A description of A and B is given below.

`val fptr` is a function that returns the (heavy-weight) function pointer to *f*. The type of `fptr` is `unit -> (`A `->` B`) C.fptr`. The encodings of argument- and result types in A and B is the same as the one used for `typ` (see below). Notice that although `fptr` is a heavy-weight value carrying run-time type information, pointer arguments within A or B still use the light-weight version!

!`val f` is an ML function that dispatches a call to *f* via `fptr`. For convenience, `f` has built-in conversions for arguments (from ML to C) and the result (from C to ML). For example, if *f* has an argument of type `double`, then `f` will take an argument of type `MLRep.Real.real` in its place and implicitly convert it to its C equivalent using `C.Cvt.c_double`. Similarly, if *f* returns an `unsigned int`, then `f` has a result type of `MLRep.Unsigned.word`. This is done for all types that have a conversion function in `C.Cvt`. Pointer values (as well as the object argument used for `struct`- or `union`-return values) are taken and returned in their heavy-weight versions. Function `f` will not be generated if the return type of *f* is incomplete.

`val f'` is the light-weight equivalent to `f.` a light-weight function. The main difference is that pointer- and object-values are passed and returned in their light-weight versions.

Type encoding rules for `(`A `->` B`) C.fptr`

A C function f's prototype is encoded as an ML type A `->` B. Calls of f from ML take an argument of type A and produce a result of type B.

- Type A is constructed from a sequence $\langle T_1, \ldots, T_k \rangle$ of types. If that sequence is empty, then $A =$ `unit`; if the sequence has only one element T_1, then $A = T_1$. Otherwise A is a tuple type T_1 `* ... *` T_k.
- If f's result is neither a `struct` nor a `union`, then T_1 encodes the type of f's first argument, T_2 that of the second, T_3 that of the third, and so on.
- If f's result is some `struct` or some `union`, then T_1 will be `(`τ `C.su, C.rw) C.obj'` with τ instantiated to the appropriate `struct`- or `union`-tag type. Moreover, we then also have $B = T_1$. T_2 encodes the type of f's *first* argument, T_3 that of the second. (In general, T_{i+1} will encode the type of the ith argument of f in this case.)
- The encoding of the ith argument of f (T_i or T_{i+1} depending on f's return type) is the light-weight ML equivalent of the C type of that argument.
- An argument of C `struct`- or `union`-type corresponds to `(`τ `C.su, C.ro) C.obj'` with τ instantiated to the appropriate tag type.
- If f's result type is `void`, then $B =$ `unit`. If the result type is not a `struct`- or `union`-type, then B is the light-weight ML encoding of that type. Otherwise $B = T_1$ (see above).

Examples

C declaration	signature of ML-side representation

`void f1 (void);`	`structure F_f1 : sig`
	`    val typ  : (unit -> unit) C.fptr C.T.typ`
	`    val fptr : unit -> (unit -> unit) C.fptr`
	`    val f    : unit -> unit`
	`    val f'   : unit -> unit`
	`end`

`int f2 (void);`	`structure F_f2 : sig`
	`    val typ  : (C.sint -> unit) C.fptr C.T.typ`
	`    val fptr : unit -> (C.sint -> unit) C.fptr`
	`    val f    : MLRep.Signed.int -> unit`
	`    val f'   : MLRep.Signed.int -> unit`
	`end`

`void f3 (int);`	`structure F_f3 : sig`
	`    val typ  : (unit -> C.sint) C.fptr C.T.typ`
	`    val fptr : unit -> (unit -> C.sint) C.fptr`
	`    val f    : unit -> MLRep.Signed.int`
	`    val f'   : unit -> MLRep.Signed.int`
	`end`

`void f4 (double, struct s*);`	`structure F_f4 : sig`
	`    val typ  : (C.double *`
	`                (ST_s.tag C.su, C.rw) C.obj C.ptr'`
	`                -> unit)`
	`                    C.fptr C.T.typ`
	`    val fptr : unit -> (C.double *`
	`                        (ST_s.tag C.su, C.rw) C.obj C.ptr'`
	`                        -> unit) C.fptr`
	`    val f    : MLRep.Real.real *`
	`               (ST_s.tag C.su, C.rw) C.obj C.ptr`
	`               -> unit`
	`    val f'   : MLRep.Real.real *`
	`               (ST_s.tag C.su, C.rw) C.obj C.ptr'`
	`               -> unit`
	`end`

C declaration	signature of ML-side representation
	`structure F_f5 : sig`
	`    val typ  : (C.float`
	`                -> (ST_s.tag C.su, C.rw) C.obj C.ptr')`
	`                    C.fptr C.T.typ`
`struct s *f5 (float);`	`    val fptr : unit -> (C.float`
`/* s incomplete */`	`                        -> (ST_s.tag C.su, C.rw) C.obj C.ptr')`
	`                            C.fptr`
	`    val f'   : MLRep.Real.real ->`
	`               (ST_s.tag C.su, C.rw) C.obj C.ptr'`
	`end`
	`structure F_f6 : sig`
	`    val typ  : (C.float`
	`                -> (S_t.tag C.su, C.rw) C.obj C.ptr')`
	`                    C.fptr C.T.typ`
	`    val fptr : unit -> (C.float`
`struct t *f6 (float);`	`                        -> (S_t.tag C.su, C.rw) C.obj C.ptr')`
`/* t complete */`	`                            C.fptr`
	`    val f    : MLRep.Real.real ->`
	`               (S_t.tag C.su, C.rw) C.obj C.ptr`
	`    val f'   : MLRep.Real.real ->`
	`               (S_t.tag C.su, C.rw) C.obj C.ptr'`
	`end`
	`structure F_f7 : sig`
	`    val typ  : ((S_t.tag C.su, C.rw) C.obj' *`
	`                C.sint * C.double`
	`                -> (S_t.tag C.su, C.rw) C.obj')`
	`                    C.fptr C.T.typ`
	`    val fptr : unit -> ((S_t.tag C.su, C.rw) C.obj' *`
	`                        C.sint * C.double`
	`                        -> (S_t.tag C.su, C.rw) C.obj')`
`struct t f7 (int, double);`	`                            C.fptr`
`/* t complete */`	`    val f    : (S_t.tag C.su, C.rw) C.obj *`
	`               MLRep.Signed.int *`
	`               MLRep.Real.real`
	`               -> (S_t.tag C.su, C.rw) C.obj`
	`    val f'   : (S_t.tag C.su, C.rw) C.obj' *`
	`               MLRep.Signed.int *`
	`               MLRep.Real.real`
	`               -> (S_t.tag C.su, C.rw) C.obj'`
	`end`

3.3 Type definitions (`typedef`)

In C a `typedef` declaration associates a type name t with a type t_C. On the ML side, t is represented by an ML structure `T_`t. This structure contains a type abbreviation `t` for the ML encoding of t_C and, provided t_C is not *incomplete*, a value `typ` of type `t C.T.typ` with run-time type information regarding t_C.

Examples

C declaration	signature of ML-side representation

`typedef int t1;`	`structure T_t1 : sig`
	`    type t   = C.sint`
	`    val typ  : t C.T.typ`
	`end`

`typedef struct s t2;`
`/* s incomplete */`
	`structure T_t2 : sig`
	`    type t  = ST_s.tag C.su`
	`end`

`typedef struct s *t3;`
`/* s incomplete */`
	`structure T_t3 : sig`
	`    type t  = (ST_s.tag C.su, C.rw) C.obj C.ptr`
	`end`

`typedef struct t t4;`
`/* t complete */`
	`structure T_t4 : sig`
	`    type t  = ST_t.tag C.su`
	`    val typ : t T.typ`
	`end`

3.4 `struct` and `union`

The type identity of a named C `struct` (or `union`) is provided by a unique ML *tag* type. There is a 1-1 correspondence between C tag names t for `struct`s on one side and ML tag types s_t on the other. An analogous correspondence exists between C tag names t for `union`s and ML tag types u_t. Notice that these correspondences are *independent of the actual declaration* of the C `struct` or `union` in question.

A C type of the form `struct` t is represented in ML as s_t `C.su`, a type of the form `union` t as u_t `C.su`. For example, this means that a heavy-weight non-constant memory object of C type `struct` t has ML type `(`s_t `C.su, C.rw) C.obj` which can be abbreviated to `(`s_t `C.su, C.rw) C.obj`.

All ML types `(`τ `C.su,` ζ`) C.obj` are originally completely abstract: they does not come with any operations that could be applied to their values. In C, the operations to be applied to a `struct`- or `union`-value is field selection. Field selection *does* depend on the actual C declaration, so it is `ml-nlffigen`'s job to generate a set of ML-side field-accessors that correspond to field-access operations in C.

Each field is represented by a function mapping a memory object of the `struct`- or `union`-type to an object of the respective field type. Let `int i;` and `const double d;` be fields of some `struct t` and let `tag` be the ML tag type corresponding to `t`. Here are the types of the (heavy-weight) access functions for `i` and `d`:

```
int i;           ⇝  val f_i :  (tag C.su, 'c) C.obj -> (C.sint, 'c) C.obj
const double d;  ⇝  val f_d :  (tag C.su, 'c) C.obj -> (C.double, C.ro) C.obj
```

Notice how each field access function is polymorphic in the `const` property of the argument object. For fields declared `const`, the result always uses `C.ro` while for ordinary fields the argument's type is used—reflecting the idea that a field is considered writable if it has not been declared `const` and, at the same time, the enclosing `struct` or `union` is writable.

Incomplete declarations

If the `struct` or `union` is incomplete (i.e., if only its tag t is known), then `ml-nlffigen` will merely generate an ML structure (called `ST_`t for `struct` and `UT_`t for `union`) with a single type `tag` that is an abbreviation for the library-defined type that corresponds to tag t.

Complete declarations

If the `struct` or `union` with tag t is complete, then `ml-nlffigen` will generate an ML structure (called `S_`t for `struct` and `U_`t for `union`) which contains at least:

`type tag` — an abbreviation for the library-defined type that corresponds to t

`val size` — a value representing information about the size of memory objects of this `struct`- or `union`-type. The ML type of `size` is `tag C.su C.S.size`.

`val typ` — a value representing run-time type information corresponding to this `struct`- or `union`-type. The ML type of `typ` is `tag C.su C.T.typ`.

Fields

In addition to `type tag`, `val size`, and `val typ`, the `ml-nlffigen` tool will generate a small set of structure elements for each field f of the `struct` or `union`. Let t_f be the type of f:

`type t_f_`f is an abbreviation for the ML encoding of t_f.

!`val typ_f_`f holds runtime type information regarding t_f. If t_f is incomplete, then `typ_f_`f is omitted.

!`val f_`f is the heavy-weight access function for f. It maps a value of type `(tag C.su, `ζ`) C.obj` to a value of type `(t_f_`f`, `ζ_f`) C.obj` and is polymorphic in ζ. If f was declared `const`, then $\zeta_f =$ `C.ro`. Otherwise $\zeta_f = \zeta$. If t_f is incomplete, then `f_`f is omitted.

`val f_`f`'` is the light-weight access function for f. It maps a value of type `(tag C.su, `ζ`) C.obj'` to a value of type `(t_f_`f`, `ζ_f`) C.obj'` and is polymorphic in ζ. If f was declared `const`, then $\zeta_f =$ `C.ro`. Otherwise $\zeta_f = \zeta$.

Bitfields

If f is a bitfield, then two access functions are generated:

`val f_`f is the heavy-weight access function, mapping values of type `(tag C.su, `ζ`) C.obj` to either ζ_f `C.sbf` or ζ_f `C.ubf`, depending on whether the type of f is `signed` or `unsigned`. The function is polymorphic in ζ. If f was declared `const`, then $\zeta_f =$ `C.ro`. Otherwise, $\zeta_f = \zeta$.

`val f_`f`'` is the light-weight access function, mapping values of type `(tag C.su, `ζ`) C.obj'` to either ζ_f `C.sbf` or ζ_f `C.ubf`, using the same conventions as those used for `f_`f.

Example

C declaration

```
struct t {
  int i;
  const double d;
  struct t *nx;
    /* complete */
  struct s *ms;
    /* incomplete */
  const int f : 2;
  unsigned g : 3;
};
```

signature of ML-side representation

```
structure S_t : sig
  type tag = ...
  val size : tag C.su C.S.size
  val typ : tag C.su C.T.typ

  type t_f_i = C.T.sint
  val typ_f_i : t_f_i C.T.typ
  val f_i  : (tag C.su, 'c) obj  -> (t_f_i, 'c) C.obj
  val f_i' : (tag C.su, 'c) obj' -> (t_f_i, 'c) C.obj'

  type t_f_d = C.T.double
  val typ_f_d : t_f_d C.T.typ
  val f_d  : (tag C.su, 'c) obj  -> (t_f_d, C.ro) C.obj
  val f_d' : (tag C.su, 'c) obj' -> (t_f_d, C.ro) C.obj'

  type t_f_nx = (tag C.su, C.rw) C.obj C.ptr
  val typ_f_nx : t_f_nx C.T.typ
  val f_nx  : (tag C.su, 'c) obj  -> (t_f_nx, 'c) C.obj
  val f_nx' : (tag C.su, 'c) obj' -> (t_f_nx, 'c) C.obj'

  type t_f_ms = (ST_s.tag C.su, C.rw) C.obj C.ptr
  val f_ms' : (tag C.su, 'c) obj' -> (t_f_ms, 'c) C.obj'

  val f_f  : (tag C.su, 'c) C.obj  -> C.ro C.sbf
  val f_f' : (tag C.su, 'c) C.obj' -> C.ro C.sbf

  val f_g  : (tag C.su, 'c) C.obj  -> 'c C.ubf
  val f_g' : (tag C.su, 'c) C.obj' -> 'c C.ubf
end
```

Unnamed `struct`s or `union`s

Each occurrence of an unnamed `struct` or `union` in C has its own type identity. The `ml-nlffigen` tool models this by artificially generating a unique tag for each such occurrence. The tags are chosen in such a way that they cannot clash with real tag names that might occur elsewhere in the C code. After choosing a fresh tag *t*, `ml-nlffigen` produces ML code according to the same rules that it uses when *t* is a real tag explicitly present in the C code.

Here are the rules for generating tags:

- If the `struct`- or `union`-declaration occurs at top level, i.e., not within the context of a `typedef` or another `struct`- or `union`-declaration, the generated tag consists of a sequence of decimal digits and can be read as a non-negative number.
- If the immediate context of the unnamed `struct` or `union` is a `typedef` for a type name *t*, then the generated tag will be `'`*t*.
- The tag of an unnamed `struct` or `union` is another (named or unnamed) `struct` or `union` with (real or generated) tag *t* is chosen to be *t*`'`*n* where *n* is a fresh sequence of decimal digits that can be read as a non-negative number.

Examples

C declaration	signature of ML-side representation
`struct {` `int i;` `};`	`structure S_0 : sig` `type tag = ...` `val size : tag C.su C.S.size` `val typ : tag C.su C.T.typ` `type t_f_i = C.T.sint` `val typ_f_i : t_f_i C.T.typ` `val f_i  : (tag C.su, 'c) obj  -> (t_f_i, 'c) C.obj` `val f_i' : (tag C.su, 'c) obj' -> (t_f_i, 'c) C.obj'` `end`
`typedef struct {` `int j;` `} s;`	`structure S_'s : sig` `type tag = ...` `val size : tag C.su C.S.size` `val typ : tag C.su C.T.typ` `type t_f_j = C.T.sint` `val typ_f_j : t_f_j C.T.typ` `val f_j  : (tag C.su, 'c) obj  -> (t_f_j, 'c) C.obj` `val f_j' : (tag C.su, 'c) obj' -> (t_f_j, 'c) C.obj'` `end`
`struct s {` `struct {` `int j;` `} x;` `};`	`structure S_s'0 : sig` `type tag = ...` `val size : tag C.su C.S.size` `val typ : tag C.su C.T.typ` `type t_f_j = C.sint` `val typ_f_j : t_f_j C.T.typ` `val f_j  : (tag C.su, 'c) C.obj  -> (t_f_j, 'c) C.obj` `val f_j' : (tag C.su, 'c) C.obj' -> (t_f_j, 'c) C.obj'` `end` `structure S_s : sig` `type tag = ...` `val size : tag C.su C.S.size` `val typ : tag C.su C.T.typ` `type t_f_x = S_s'0.tag C.su` `val typ_f_x : t_f_x C.T.typ` `val f_x  : (tag C.su, 'c) C.obj  -> (t_f_x, 'c) C.obj` `val f_x' : (tag C.su, 'c) C.obj' -> (t_f_x, 'c) C.obj'` `end`

3.5 Enumerations (`enum`)

A C enumeration of constants $c_1, c_2, \ldots, c_k$ declared via `enum` is represented by k ML values of a chosen ML representation type. By default, that type is `MLRep.Signed.int`, i.e., the same type that also represents the C type `int`. A command line switch (`-enum-constructors` or `-ec`) to `ml-nlffigen` can change this behavior in such a way that whenever possible the representation type for an enumeration becomes an ML datatype, thus making it possible to perform pattern-matching on constants. The representation type cannot be a datatype if two or more `enum` constants share the same value as in:

```
enum ab { A = 12, B = 12 };
```

Complete enumerations

Let t be the tag of the C `enum` declaration, and let $c_1, \ldots, c_k$ be its set of constants. The ML-side representative of such a declaration is a structure `E_`t which contains $10 + k$ elements, the first 10 being:

`type tag` The ML-side encoding of type `enum` t is `tag C.enum`. Values of this type are abstract. They can be converted to and from concrete integer values of type `MLRep.Signed.int` using `C.Cvt.c2i_enum` and `C.Cvt.i2c_enum`, respectively. Like in the case of `struct` or `union`, type `tag` is an abbreviation for the pre-defined type that uniquely corresponds to the tag name t.

`type mlrep` This is the type of concrete ML-side values representing the $c_1, \ldots, c_k$. This type is not the same as `tag C.enum` and defaults to `MLRep.Signed.int`. As mentioned above, by specifying the `-enum-constructors` or `-ec` command-line flag one can force `ml-nlffigen` to generate a datatype definition for type `mlrep`.

`val m2i` This is a function for converting `mlrep` values to values of type `MLRep.Signed.int`. If the former is the same type as the latter (see above), then `m2i` is the identity function. Otherwise `ml-nlffigen` generates explicit code to map each `mlrep` constructor to an integer value.

`val i2m` This is the inverse of `m2i`. If `mlrep` is a datatype, then `m2i` will raise exception `Domain` when the argument does not correspond to one of the constructors.

`val c` Function `c` converts values of type `mlrep` to values of type `tag C.enum`. It is merely a composition of `C.Cvt.i2c_enum` and `m2i`.

`val ml` Function `ml` is the composition of `i2m` and `C.Cvt.c2i_enum` and converts values of type `tag C.enum` to values of type `mlrep`. It can raise exception `Domain` if the C type system had been subverted (which is always a real possibility).

`val get` Function `get` fetches a value of type `mlrep` from a memory object of type `(tag C.enum,` ζ`) C.obj`. It is a composition of `i2m` and `C.Get.enum`.

`val get'` Function `get'` fetches a value of type `mlrep` from a memory object of type `(tag C.enum,` ζ`) C.obj'`. It is a composition of `i2m` and `C.Get.enum'`.

`val set` Function `set` stores a value of type `mlrep` into a memory object of type `(tag C.enum, C.rw) C.obj`. It is a composition of `m2i` and `C.Set.enum`.

`val set'` Function `set'` stores a value of type `mlrep` into a memory object of type `(tag C.enum, C.rw) C.obj'`. It is a composition of `m2i` and `C.Set.enum'`.

Each of the remaining k elements corresponds to one of the enumeration constants c_i. Concretely, the element generated for c_i is `val e_`c_i and has type `mlrep`. If `mlrep` is a datatype, then the `e_`c_i are constructors which can be used in ML patterns.

Examples

C declaration	signature of ML-side representation
	`structure E_e : sig`
	`    type tag = ...`
	`    type mlrep = MLRep.Signed.int`
	`    val e_A  : mlrep  (* = 0 *)`
	`    val e_B  : mlrep  (* = 1 *)`
	`    val e_C  : mlrep  (* = 2 *)`
	`    val m2i  : mlrep -> MLRep.Signed.int`
`enum e { A, B, C };`	`    val i2m  : MLRep.Signed.int -> mlrep`
`/* default treatment */`	`    val c    : mlrep -> tag C.enum`
	`    val ml   : tag C.enum -> mlrep`
	`    val get  : (tag C.enum, 'c) C.obj  -> mlrep`
	`    val get' : (tag C.enum, 'c) C.obj' -> mlrep`
	`    val set  : (tag C.enum, C.rw) C.obj  * mlrep -> unit`
	`    val set' : (tag C.enum, C.rw) C.obj' * mlrep -> unit`
	`end`
	`structure E_e : sig`
	`    type tag = ...`
	`    datatype mlrep = e_A | e_B | e_C`
	`    val m2i  : mlrep -> MLRep.Signed.int`
	`    val i2m  : MLRep.Signed.int -> mlrep`
`enum e { A, B, C };`	`    val c    : mlrep -> tag C.enum`
`/* -enum-constructors */`	`    val ml   : tag C.enum -> mlrep`
	`    val get  : (tag C.enum, 'c) C.obj  -> mlrep`
	`    val get' : (tag C.enum, 'c) C.obj' -> mlrep`
	`    val set  : (tag C.enum, C.rw) C.obj  * mlrep -> unit`
	`    val set' : (tag C.enum, C.rw) C.obj' * mlrep -> unit`
	`end`
	`structure E_e : sig`
	`    type tag = ...`
	`    type mlrep = MLRep.Signed.int`
	`    val e_A  : mlrep  (* = 0 *)`
	`    val e_B  : mlrep  (* = 1 *)`
	`    val e_C  : mlrep  (* = 0 *)`
`enum e { A = 0, B = 1,`	`    val m2i  : mlrep -> MLRep.Signed.int`
`         C = 0 };`	`    val i2m  : MLRep.Signed.int -> mlrep`
`/* with or without`	`    val c    : mlrep -> tag C.enum`
` *  -enum-constructors */`	`    val ml   : tag C.enum -> mlrep`
	`    val get  : (tag C.enum, 'c) C.obj  -> mlrep`
	`    val get' : (tag C.enum, 'c) C.obj' -> mlrep`
	`    val set  : (tag C.enum, C.rw) C.obj  * mlrep -> unit`
	`    val set' : (tag C.enum, C.rw) C.obj' * mlrep -> unit`
	`end`

Incomplete enumerations

If the enumeration is incomplete, i.e., if only its tag *t* is known, then no structure `E_`*t* is generated. Instead, a structure `ET_`*t* takes its place which merely contains the type `tag` as described above.

Unnamed enumerations

Anonymous enumerations (`enum`s without a tag) are handled in a way that is very similar to the treatment of unnamed `struct`s and `union`s. In particular, the rules for assigning a generated tag are the same if the `enum` occurs in the context of a `typedef` or another `struct` or `union`.

However, by default all constants in unnamed top-level `enum`s get collected into one single virtual enumeration whose tag is `'` (apostrophe). If this is not desired, then the command line flag `-nocollect` turns this off and lets `ml-nlffigen` fall back to the exact same rules that are used for unnamed top-level `struct`s and `union`s: a fresh "numeric" tag gets generated for each such `enum`.

Examples for collected unnamed enumerations

C declaration	signature of ML-side representation

`enum { A, B };`
`enum { C, D };`
`/* with or without`
` *  -enum-constructors */`
	`structure E_' : sig`
	`    type tag = ...`
	`    type mlrep = MLRep.Signed.int`
	`    val e_A  : mlrep  (* = 0 *)`
	`    val e_B  : mlrep  (* = 1 *)`
	`    val e_C  : mlrep  (* = 0 *)`
	`    val e_D  : mlrep  (* = 1 *)`
	`    ...`
	`end`

`enum { A, B };`
`enum { C = 2, D };`
`/* -enum-constructors */`
	`structure E_' : sig`
	`    type tag = ...`
	`    datatype mlrep = e_A | e_B | e_C | e_D`
	`    ...`
	`end`