CSE 341:
Programming Languages

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Lecture 4—“One-of” types; user-defined types; pattern-matching
Where are we

- Done features: functions, tuples, lists, local bindings
- Done concepts: syntax vs. semantics, environments, mutation-free
- Today features: record types, datatypes, type synonyms, pattern-matching
- Today concepts: “One-of” types, constructors/destructors, case-coverage
Base types and compound types

Languages typically provide a small number of “built-in” types and ways to build compound types out of simpler ones:

- Base types examples: int, bool
- Type builder examples: tuples, lists, records

Base types clutter a language definition; better to make them libraries when possible.

- ML does this to a remarkable extent (e.g., we will soon define away bool and conditionals)

Good to let programmers bind types to type names, just like we bind values to variables.
Compound-type flavors

Conceptually, just a few ways to build compound types:

1. “Each-of”: A t contains a t1 and a t2
2. “One-of”: A t contains a t1 or a t2
3. “Self-reference”: The definition of t may refer to t

Examples:

• int * bool
• int option
• int list

Remarkable: A lot of data can be described this way.

(optional) jargon: Product types, sum types, recursive types
User-defined types

There are many reasons to define your own types:

1. Using a tuple with 12 fields is incomprehensible

2. Writing down large types is unpleasant; we have computers for that

3. Large programs can use abstract types to be robust to change
   • A couple weeks ahead

4. So the language doesn’t have to “bake in” lists and options and ...
Datatype

One-of types are less similar across languages

- We’ll discuss OO’s approach to one-of in a few weeks

In ML, we use a datatype binding, e.g.:

datatype mytype = TwoI of int*int | Str of string | Pizza

Semantics: Extend the environment with

- a new type, mytype
- three constructors (in part, functions/constants that produce values of type mytype)

So we have a way to build them... what's missing?
The old way

For lists, we had a way to:

- Test which *variant* a value was
- Extract the values from *value-carrying* variants
  - Makes no sense if you have the *wrong* variant

What would this look like for *mytype*?
The new way

Rather than add *variant-tests* and *variant-destructors* (non-standard jargon and nothing to do with C++ destructors), ML has a *case expression* that uses *pattern-matching*.

In its simplest form, case has one pattern for each constructor in a datatype and binds one variable for each value carried. Example:

```plaintext
    case e of
        TwoI(i1,i2) => e1
    | Str s => e2
    | Pizza => e3
```

What are the evaluation rules?
What are the typing rules?
Type-checking case

In addition to binding local variables and requiring branches to have the same type, the typing rules for case prevent some run-time errors:

- Exhaustiveness: No test can “fail” (a warning)
- Redundancy: No test can be “impossible” (an error)

So far, case gives us what we need to use datatypes:

- A (combined) way to test variants and extract values
- Powerful enough to define our own tests and destructors

In fact, pattern-matching is far more general and elegant:

- Can use it for datatypes already in the top-level environment
- Can use it for any type (Wednesday)
- Can have deep patterns (Wednesday)