CSCI 334:
Principles of Programming Languages

Lecture 15: ML, part 2

Instructor: Dan Barowy

Williams

Topics

Pattern matching

Algebraic data types

Option type

Your to-dos

1. Lab 6, **due Sunday 4/10** (partner lab)
2. Reading response, **due Wednesday 4/13**.

Announcements

Colloquium on Friday.

Friday, April 8 @ 2:35pm

Wege Hall – TCL 123

Perception and Context in Data Visualization

Jordan Crouser, Smith College

Visual analytics is the science of combining interactive visual interfaces and information visualization techniques with automatic algorithms to support analytical reasoning through human-computer interaction. People use visual analytics tools and techniques to synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data… and we exploit all kinds of perceptual tricks to do it! In this talk, we'll explore concepts in decision-making, human perception, and color theory as they apply to data-driven communication. Whether you're an aspiring data scientist or you're just curious about the mechanics of how data visualization works under the hood, stop by and take your pre-attentive processing for a spin.

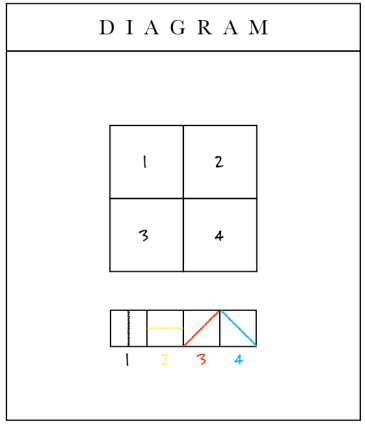
Announcements

- **ACM TechTalk: "Visual Data Analysis: Why? When? How?"**
  Organized by Prof. Kelly Shaw and CoSSAC.
  Wednesday, April 13 from 7-7:45pm in TBL 211.
  Extra special snacks provided by CoSSAC afterward in the Eco Cafe.

Announcements

- **Field trip to WCMA**, Tuesday, April 12.
  Bring your handout from our first trip.
- **Fixed** a handful of **typos** in the F# chapters of the course packet— see updated PDF online.
- Today's **office hours end at 5pm** (sorry!)

A small addendum to lab 6.



A square divided horizontally and vertically into four equal parts, each with a different color and line direction.

Red, yellow, blue, black pencil

More Inspiration for Projects

Pattern Matching

Pattern matching

```
let rec product nums =
  if (nums = []) then
    1
  else
    (List.head nums)
    * product (List.tail nums)
```

Using **patterns**…

```
let rec product nums =
  match nums with
  | []    -> 1
  | x::xs -> x * product xs
```

Pattern matching

A **pattern** is built from

- **values**,
- (de)**constructors**,
- and **variables**

Tests whether values match “pattern”

If yes, values bound to variables in pattern

Pattern matching

```
let rec product nums =
  if (nums = []) then
    1
  else
    (List.head nums)
    * product (List.tail nums)
```

Using **patterns**…

```
let rec product nums =
  match nums with
  | []    -> 1
  | x::xs -> x * product xs
```

Activity: Pattern matching on integers

Write a function `listOfInts` that returns a list of integers from **zero** to `n`.

```
let rec listOfInts n =
  match n with
  | 0 -> [0]
  | i -> i :: listOfInts (i - 1)
```

Oops! This returns the list backward.

Let's flip it around.

Revisiting local declarations

Let's fix our code the lazy way…

```
let listOfInts n =
  let rec li n =
    match n with
    | 0 -> [0]
    | i -> i :: listOfInts (i - 1)
  li n |> List.rev
```

… by defining a function inside our function.

Pattern matching on lists

- Remember, a list is one of two things:
  - `[]`
  - `<first elem> :: <rest of elems>`
  - E.g., `[1; 2; 3] = 1::[2,3] = 1::2::[3] = 1::2::3::[]`
- Can define function by cases…

```
let rec length xs =
  match xs with
  | []    -> 0
  | x::xs -> 1 + length xs
```

Activity: Pattern matching on tuples

Write a **function** that computes the **Cartesian product** of two sets, represented by lists:

$$A \times B = \{ (a,b) \mid a \in A \text{ and } b \in B \}$$

Hint: I find it helpful to think about **base cases** first.

```
let rec cartesianProduct xs ys =
  match xs,ys with
  | []    ,_   -> []
  | _     ,[] -> []
  | x::xs',_   ->
    let zs = ys |> List.map (fun y -> (x,y))
    zs @ cartesianProduct xs' ys
```

Patterns in declarations

- Patterns can be used in place of variables
- Most basic pattern form
  - `let <pattern> = <exp>`
- Examples
  - `let x = 3`
  - `let tuple = ("moo", "cow")`
  - `let (x,y) = tuple`
  - `let myList = [1; 2; 3]`
  - `let w::rest = myList`
  - `let v::_ = myList`

Algebraic Data Types*

*not to be confused with Abstract Data Types!

Algebraic Data Type

An **algebraic data type** is a composite data type, made by combining other types in one of two different ways:

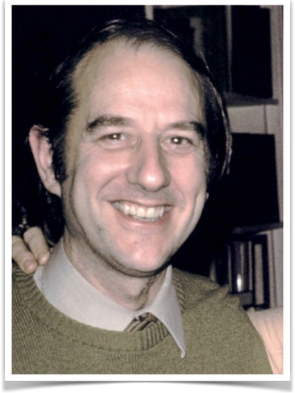
- by **product**, or
- by **sum**.

You've already seen **product types**: tuples and records.

So-called b/c the set of all possible values of such a type is the cartesian product of its component types.

We'll focus on **sum types**.

Algebraic Data Types



- Invented by Rod Burstall at University of Edinburgh in '70s.
- Part of the HOPE programming language.
- Not useful without pattern matching.
- Like peanut butter and chocolate, they are "better together."

A “move” function in a game

A “move” function in a game (Java)

```
public static final int NORTH = 1;
public static final int SOUTH = 2;
public static final int EAST = 3;
public static final int WEST = 4;

public … move(int x, int y, int dir) {
  switch (dir) {
    case NORTH: ...
    case ...
  }
}
```

A “move” function in a game (Java)

Discriminated Union (sum type)

```
type Direction =
     North | South | East | West;

let move coords dir =
  match coords,dir with
  |(x,y),North -> (x,y - 1)
  |(x,y),South -> (x,y + 1)
```

- Above is an “incomplete pattern”
- ML will warn you when you’ve missed a case!
  - “proof by exhaustion”

Parameters

```
type Shape =
    | Rectangle of float * float
    | Circle of float
```

- Pattern match to extract parameters

```
let s = Rectangle(1.0,4.0)
match s with
| Rectangle(w,h) -> …
| Circle(r) -> …
```

Named parameters

```
type Shape =
    | Rectangle of width: float * height: float
    | Circle of radius: float
```

- Names are really only useful for initialization, though.

```
let s = Rectangle(height = 1.0, width = 4.0)
```

ADTs can be recursive and generic

```
type MyList<'a> =
      | Empty
      | NonEmpty of head: 'a * tail: MyList<'a>
```

```
> NonEmpty(2, Empty);;
    val it : MyList<int> = NonEmpty (2,Empty)
```

Avoiding errors with patterns

- Another example: handling errors.
- SML has exceptions (like Java)
- But an alternative, easy way to handle many errors is to use the option type:

```
type option<'a> =
| None
| Some of 'a
```

Avoiding errors with patterns

```
let divide quot div =
  match div with
  | 0 -> None
  | _ -> Some (float quot/float div)
```

Avoiding errors with patterns

```
> divide 6 7;;
val it : float option = Some 0.8571428571

> divide 6 0;;
val it : float option = None

>
```

option type

- Why `option`?
- `option` is a data type;

  not handling errors is a static type error!

Recap & Next Class

Today:

Pattern matching

Algebraic data types

Option type

Next class:

WCMA!