LING 473 – Project 3
Summer 2015

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Preamble

For this project, we are given an input block of Thai data. As mentioned in the notes, it is common in Thai orthography to not separate word and/or syllable breaks by spaces. The goal here is to use a state machine to parse the input and return the correct word / syllable breaks via the provided sets of vowels, consonant and tone marks.

The input for this program is found at the following location on PATAS:

/opt/dropbox/15-16/473/project3/fsm-input.utf8.txt.

Programming Environment and File Set

Once again, I chose the C# language for this project as implemented under the Mono platform. The code was developed using Xamarin Studio on my Mac OS X computer.

When I began this project, I made use of a simple switch / case construct to model the correct state transitions. After that work was completed, I decided to try and implement a second version of the machine using the Dictionary object states and Func<> objects (with the related lambdas). Because of their common functionally, I also created an interface type to model the core behavior of the machine.

This all being said, I ended up with the following files:

- **Program.cs**: Program Entry Point
- **IThaiSyllabifier.cs**: Interface definition.
- **ThaiSyllabifierCaseLogic.cs**: State machine using switch / case logic.
- **ThaiSyllabifierLambdaLogic.cs**: State machine using lambdas / Func<> objects.
- **StateReturnData.cs**: Currently, my lambda-centric state machine requires the use of a custom class to encapsulate the returned state and text output….this is where I am currently stuck (see below).

Full disclosure! At the time I am authoring this write up- the ThaiSyllabifierLambdaLogic class does not work correctly- I am hoping that I can figure out my error as I go through the write up! But, as far as I can tell, the case logic works fine.

A walkthrough of the key code points can be found over the next several pages.

The Common Interface and Core Main() Logic

Both of my state machine implement the following interface:

```
public interface IThaiSyllabifier
{
   void SyllabifyString(string input);
   string GetOutputString();
}
```

As you can see, the SyllabifyString() method will take a line of Thai input and insert breaks based on the provided state machine notes.

I am returning void from this method. Initially I returned a string- but once I started doing the lambda version of the machine, I realized I needed to return other data (at least it seems that way). Given this, the shared interface also provides a method named GetOutputString() which will returned the syllabified string. I think I would clean this up if I had time- but this is what I am going with for now!

Given that ThaiSyllabifierCaseLogic and ThaiSyllabifierLambdaLogic both implement this interface, I created a simple factory method which will return the correct underlying object based on the presence of –lambda in the command line arguments (this method is in the Program class):

```
static IThaiSyllabifier BreakerFactoryMethod(string[] args)
{
   // See if user wants to use lambda version.
   if (args.Contains ("-lambda"))
      usingLambda = true;

   // Create the buster.
   IThaiSyllabifier breaker = null;
   if (!usingLambda)
      breaker = new ThaiSyllabifierCaseLogic ();
   else
      breaker = new ThaiSyllabifierLambdaLogic ();

   return breaker;
}
```

The Main() method uses the underlying object as so (htmlOutput is a StringBuilder object):

```
// Now loop over each line in the input file and write it out.
foreach (var currLine in File.ReadAllLines(inputFileLocation))
{
  breaker.SyllabifyString (currLine);
  htmlOutput.Append(breaker.GetOutputString());
  htmlOutput.Append("<br/>");
}
```

The last thing to mention at this point is that I did create a secondary interface during my programming time- but it is not currently used. The problem (as you will see) is how each machine handles processing the text characters and how it is returned back.

```
// I made a sub-interface- because the GetOutputString()
// already works for the case logic by returning a string.
// Do I need this?
// Currently not used!!
public interface ILambdaSupport : IThaiSyllabifier
{
    StateReturnData SyllabifyStringLambda(string input);
}
```

The ThaiSyllabifierCaseLogic Implementation

I was *really* surprised how quick (and straightforward) it was to implement the machine using a switch statement (and your notes!). I've read about state machines and did some pencil and paper work before- but this was my first time coding such a construct.

First, my class has member variables for each of the HashSets<> you listed in the assignment notes:

```
public class ThaiSyllabifierCaseLogic : IThaiSyllabifier
{
   #region Vowels, consonants and tones!
   // These HashSet objects contain the possible characters which can correspond to the
   // following input pattern:
   // [V1]C1[C2][V2][T][V3][C3]
   private HashSet<char> vowelSet1 = new HashSet<char>("ุูิีั");
…
   #endregion
…
}
```

Next, I make use of the following C# enum to mark each state (this machine does not use the State.Error value- but the other machine does, so I included it here):

```
// This enum defines the various states the machine can be in.
public enum State {Zero, One, Two, Three, Four, Five, Six, Seven, Eight, Nine, Error};
```

The SyllabifyString() method of the shared interface is implemented using the following algorithm:

- The machine states in State.Zero.
- Take the current input string object and loop over each character.
- Test if the current character is a member of any of the HashSet<> objects using a series of case statements.
- If a match is found, change to the new state (as listed in the assignment notes).
- If we reach an accepting state (State.Seven, State.Eight or State.Nine) we will either add a space before the character in question, or break at that point.

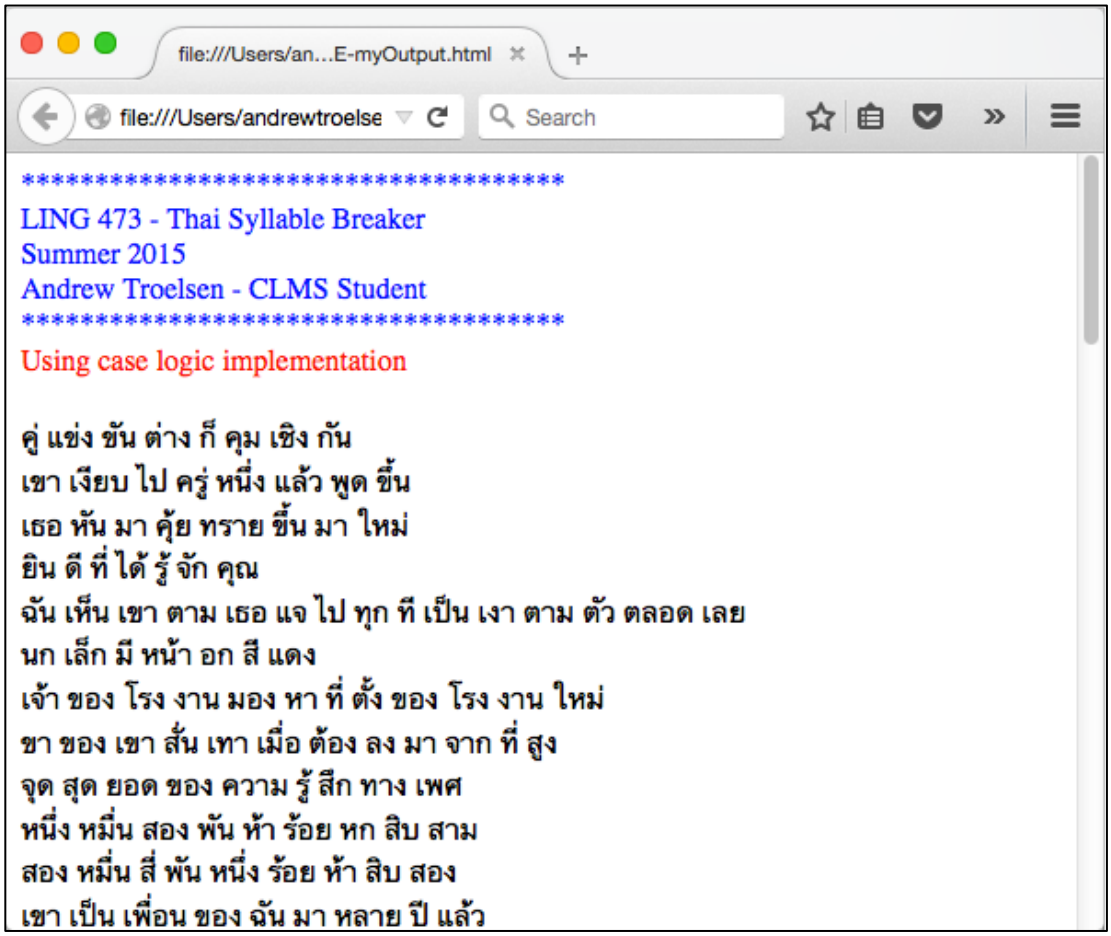
The full implementation of this method is quite long- so I won't repeat everything here. However, the next page showcases the crux of the logic:

```
public void SyllabifyString (string input)
{
   State currentState = State.Zero;

   outputString = new StringBuilder(input);

   // Loop over each character in the input.
   for(int currCharPos = 0; currCharPos < outputString.Length; currCharPos++)
   {
      // Switch on the current state.
      // When in a state, we will check the current character's membership
      // in a given HashSet<> and then transition to next state.
      switch (currentState)
      {
…
   case State.Two:

      if (conSet2.Contains (outputString[currCharPos]))
         currentState = State.Three;
      else if (vowleSet2.Contains (outputString[currCharPos]))
         currentState = State.Four;
      else if (toneSet.Contains (outputString[currCharPos]))
         currentState = State.Five;
      else if (vowelSet3.Contains (outputString[currCharPos]))
         currentState = State.Six;
      else if (conSet3.Contains (outputString[currCharPos]))
         currentState = State.Nine;
      else if (vowelSet1.Contains (outputString[currCharPos]))
         currentState = State.Seven;
      else if (conSet1.Contains (outputString[currCharPos]))
         currentState = State.Eight;
      break;
…
   case State.Seven: // Syllable break!
      currentState = State.One;
      outputString = outputString.Insert (currCharPos - 1, " ");
      break;

   case State.Eight: // Syllable break!
      currentState = State.Two;
      outputString = outputString.Insert (currCharPos - 1, " ");
      break;

   case State.Nine: // Syllable break!
      currentState = State.Zero;
      outputString = outputString.Insert (currCharPos, " ");
      break;
…
}
```

The implementation of the GetOutputString() method is simply to return the "broken" input text:

```
public string GetOutputString()
{
   return outputString.ToString();
}
```

So! If you run the program and do not provide the –lambda command line argument, the program will generate an HTML file named myOutput.html. When I load this up into a web browser, I find the following (partial) output:



By doing an eye-ball comparison of the fsm-output (intended).html file found in the /opt/dropbox/15-16/473/project3 folder, it appear to be the correct output!

The ThaiSyllabifierLambdaLogic Implementation

As mentioned- this is currently not working. I've tried several iterations of this, but I am stuck at the same place each time. I will describe what I have tried so far (you can see all the commented attempts in the C# code file). If I am lucky, maybe I'll have an "AH-HA!" moment while typing.

So, this class still makes use of a custom State enum. No changes there. The class also implements the common interface.

The biggest change is the use of a (massive) Dictionary<> object- I used your slides in lecture 8 as a template. My first iteration of this object mapped each case statement from the other machine using the same technique:

- The Dictionary<> is typed to operate of <State, Func<char,State>> tuples.
- The input to Func<> is the current character to look at. The return value is the new state.

In this partial implementation, you can see where I was trying to go:

```
private Dictionary<State, Func<char, State>> stateMachine = new Dictionary<State, Func<char, State>>
{
   {State.Zero, (ch) => {
                        if (vowelSet1.Contains (outputString[ch]))
                           return State.One;
                        else if (conSet1.Contains (outputString[ch]))
                           return State.Two;
                        else return State.Error; } },

   {State.One, (ch) => {
         if (conSet1.Contains (outputString[ch]))
            return State.Two;
         else return State.Error; }},
  …
}
```

I was able to get a clean compile, but I was receiving a null reference exception because the StringBuilder object (outputString) was not initialized. Suddenly I realized this approach would not really work, because this object can't be constructed to hold the current input string until after the Dictionary is created!

<< Thought- I could move this dictionary object as a local variable to the SyllabifyString() method! I will try that after I talk about my other attempts. >>

In my second attempt, I thought maybe a way around this scope problem was to have the Dictionary not simply return the new state, but a new class which holds the state and the current form of the output string (which was a StringBuilder at this point). The class was defined as so:

```
public class StateReturnData
{
   // The lambda version of the machine requires multiple
   // return values- so using this class type.
   public ThaiSyllabifierLambdaLogic.State newState;
   public StringBuilder outputString;

   public StateReturnData(ThaiSyllabifierLambdaLogic.State newState, StringBuilder outputString)
   {
      this.newState = newState;
      this.outputString = outputString;
   }
}
```

With this, the Func<> now looked like so:

```
Func<char, StateReturnData>
```

Some example dictionary entries now looked like so:

```
{State.Zero, (ch) => {
      if (vowelSet1.Contains (outputString[ch]))
         return new StateReturnData(State.One, outputString);
      else if (conSet1.Contains (outputString[ch]))
         return new StateReturnData(State.Two, outputString);
      else return new StateReturnData(State.Error, outputString); } },
...
{ State.Seven, (ch) => {
      outputString = outputString.Insert (ch - 1, " ");
      return new StateReturnData(State.One, outputString);}},

{ State.Eight, (ch) => {
      outputString = outputString.Insert (ch - 1, " ");
      return new StateReturnData(State.Two, outputString);}},

{ State.Nine, (ch) => {
      outputString = outputString.Insert (ch, " ");
      return new StateReturnData(State.Zero, outputString);}}
```

Again, I did get a clean compile….but got a stack overflow exception at runtime :-/
So it seemed that I was copying way too many StringBuilder objects and growing the internal character buffer too far.

So I changed this class to look like so:

```
public class StateReturnData
{
   // The lambda version of the machine requires multiple
   // return values- so using this class type.
   public ThaiSyllabifierLambdaLogic.State newState;
   public StringBuilder outputString = new StringBuilder();

   public StateReturnData(ThaiSyllabifierLambdaLogic.State newState, string outputString)
   {
      this.newState = newState;
      this.outputString.Append(outputString);
   }
}
```

In this case, notice I am attempting to use Append() rather than a straight assignment.

With this change, I went to my third attempt at the massive Dictionary<> object- which is where I am currently stuck.

Now, rather than having a dictionary entry try to consult the outputString object (which again, is currently not holding the input text!! See my realization in yellow above….) I am trying to take the input character and directly consult the HashSet<> objects. For example:

```
{State.Two, (ch) => {
      if (conSet2.Contains (ch))
         return new StateReturnData(State.Three, ch.ToString());
      else if (vowleSet2.Contains (ch))
         return new StateReturnData(State.Four, ch.ToString());
      else if (toneSet.Contains (ch))
         return new StateReturnData(State.Five, ch.ToString());
      else if (vowelSet3.Contains (ch))
         return new StateReturnData(State.Six, ch.ToString());
      else if (conSet3.Contains (ch))
         return new StateReturnData(State.Nine, ch.ToString());
      else if (vowelSet1.Contains (ch))
         return new StateReturnData(State.Seven, ch.ToString());
      else if (conSet1.Contains (ch))
         return new StateReturnData(State.Eight, ch.ToString());
      else return new StateReturnData(State.Error, ch.ToString()); }},
```

Because I was no longer referencing the outputString object, I had to change how I handled states Seven, Eight and Nine by building a temp string object via string.Format. Basically the location of the {0} insertion point is accounting for where to add a space (or not):

```
{State.Seven, (ch) => {
      //outputString = outputString.AppendFormat (" {0}", ch.ToString());
      return new StateReturnData(State.One, string.Format(" {0}", ch.ToString())); }},

{State.Eight, (ch) => {
      //outputString = outputString.AppendFormat (" {0}", ch.ToString());
      return new StateReturnData(State.Two, string.Format(" {0}", ch.ToString())); }},

{State.Nine, (ch) => {
      //outputString = outputString.AppendFormat ("{0} ", ch.ToString());
      return new StateReturnData(State.Zero, string.Format("{0}", ch.ToString())); }},
```

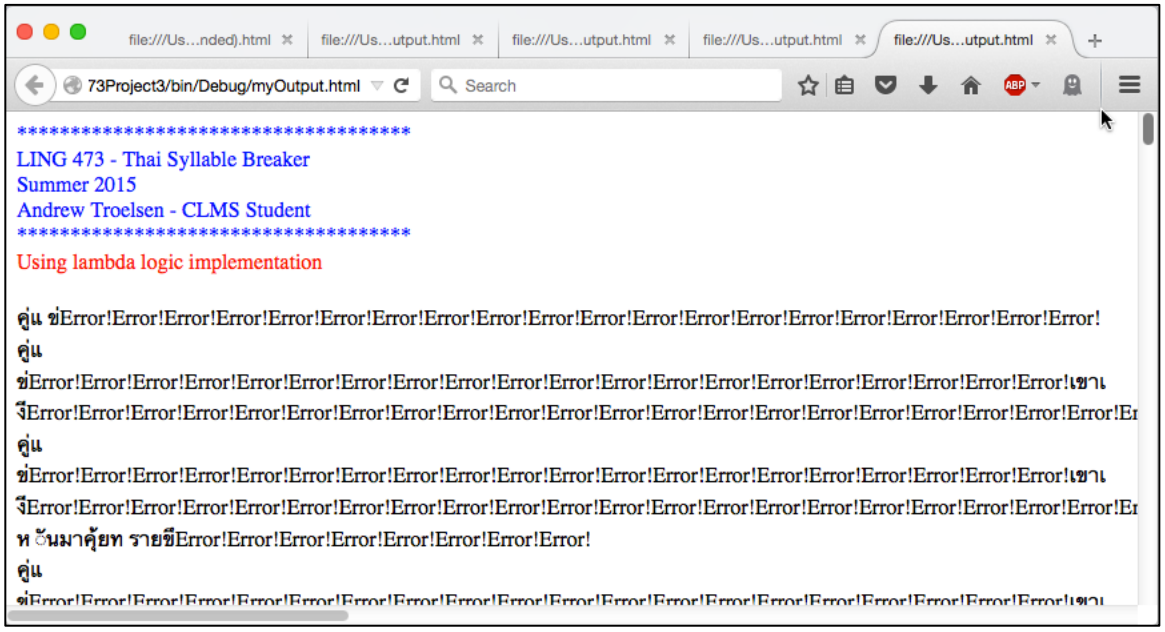
I also added an entry for State.Error like so:

```
{State.Error, (ch) => { return new StateReturnData(State.Error, "Error!");}}
```

Now, here is my current problem!! Most of my Func<> listings have a final “else if” which always transitions to State.Error:

```
{State.Six, (ch) => {
      if (conSet3.Contains (ch))
         return new StateReturnData(State.Nine, ch.ToString());
      else if (vowelSet1.Contains (ch))
         return new StateReturnData(State.Seven, ch.ToString());
      else if (conSet1.Contains (ch))
         return new StateReturnData(State.Eight, ch.ToString());
      else return new StateReturnData(State.Error, ch.ToString()); }},
```

So when I run this iteration- I no longer get a runtime exception (that is nice) but my output is 95% “Error!” tokens:



So this is where I was before I started doing my write up.

See next page for possible breakthrough!

Last Ditch Effort

So during this write up I realized my outputBuffer could never be initialized with the input Thai text, *because* the Dictionary was a class level variable. So I will now try to move the first iteration of the Dictionary into the scope of the SyllabifyString() method (screen shot to prevent huge dump of Dictionary contents):

```
public void SyllabifyString (string input)
{
    MASSIVE Dictionary of states and transitions!

    // StateReturnData state = new StateReturnData(State.Zero, "");
    State state = State.Zero;

    outputString = new StringBuilder(input);

    // Loop over each character in the input.
    for (int currCharPos = 0; currCharPos < outputString.Length; currCharPos++)
    {
        state = stateMachine [state] (outputString[currCharPos]);
    }
}
```

Nope. Now I am getting an index out of range error. Grrrr.

```
Dictionary<State, Func<char, State>> stateMachine = new Dictionary<State, Func<char, State>>
{
    {State.Zero, (ch) => {
                if (vowelSet1.Contains (outputString[ch]))
                    return State.One;
                else if (conSet1.Contains (outputString[ch]))
                    return State.Two;
                else return State.Error; } },
```

System.IndexOutOfRangeException has been thrown
Array index is out of range.
Show Details

~~Well Glenn, I think I am close here- but I really need to move onto the next program assignment this weekend. So I think I will leave this "as-is" for now. If I have time I really want to come back to this and see if I can figure it out. I think I am close! But I have my in-laws coming to visit next week, so I need to start on Project 4!!~~

~~Thanks!~~

I figured it out! I put the Dictionary object within the scope of the SyllabifyString() method. I also realized I was strangely not noticing that I was trying to index into the StringBuilder using the current CHARACTER not the current CHARACTER COUNT!!! That is why I was getting the index out of range exception above. So I fixed that- and I did not need that extra class for the return value after all.

Just because I am so darn happy now- I'll list out the entire implementation on the next page (or two) ☺

```
public void SyllabifyString (string input)
{
   // Make this visible to the whole method.
   int currCharPos = 0;

   #region MASSIVE Dictionary of states and transitions!
   // This dictionary holds a list of Func<> objects, which take the current character as input, and return the
   // new state.
   Dictionary<State, Func<char, State>> stateMachine = new Dictionary<State, Func<char, State>>
   {
      {State.Zero, (ch) => {
            if (vowelSet1.Contains (ch))
               return State.One;
            else if (conSet1.Contains (ch))
               return State.Two;
            else return State.Error; } },

      {State.One, (ch) => {
            if (conSet1.Contains (ch))
               return State.Two;
            else return State.Error; }},

      {State.Two, (ch) => {
            if (conSet2.Contains (ch))
               return State.Three;
            else if (vowleSet2.Contains (ch))
               return State.Four;
            else if (toneSet.Contains (ch))
               return State.Five;
            else if (vowelSet3.Contains (ch))
               return State.Six;
            else if (conSet3.Contains (ch))
               return State.Nine;
            else if (vowelSet1.Contains (ch))
               return State.Seven;
            else if (conSet1.Contains (ch))
               return State.Eight;
            else return State.Error; }},

      {State.Three, (ch) => {
            if (vowleSet2.Contains (ch))
               return State.Four;
            else if (toneSet.Contains (ch))
               return State.Five;
            else if (vowelSet3.Contains (ch))
               return State.Six;
            else if (conSet3.Contains (ch))
               return State.Nine;
            else return State.Error; }},


      {State.Four, (ch) => {
            if (toneSet.Contains (ch))
               return State.Five;
            else if (vowelSet3.Contains (ch))
               return State.Six;
```

```
            else if (conSet3.Contains (ch))
               return State.Nine;
            else if (vowelSet1.Contains (ch))
               return State.Seven;
            else if (conSet1.Contains (ch))
               return State.Eight;
            else return State.Error; }},

        {State.Five, (ch) => {
            if (vowelSet3.Contains (ch))
               return State.Six;
            else if (conSet3.Contains (ch))
               return State.Nine;
            else if (vowelSet1.Contains (ch))
               return State.Seven;
            else if (conSet1.Contains (ch))
               return State.Eight;
            else return State.Error; }},

        {State.Six, (ch) => {
            if (conSet3.Contains (ch))
               return State.Nine;
            else if (vowelSet1.Contains (ch))
               return State.Seven;
            else if (conSet1.Contains (ch))
               return State.Eight;
            else return State.Error; }},


        {State.Seven, (ch) => {
            outputString = outputString.Insert (currCharPos - 1, " ");
            return State.One;}},

        {State.Eight, (ch) => {
            outputString = outputString.Insert (currCharPos - 1, " ");
            return State.Two;}},

        {State.Nine, (ch) => {
            outputString = outputString.Insert (currCharPos, " ");
            return State.Zero;}}
    };
    #endregion

    // StateReturnData state = new StateReturnData(State.Zero, "");
    State state = State.Zero;

    outputString = new StringBuilder(input);

    // Loop over each character in the input.
    for (currCharPos = 0; currCharPos < outputString.Length; currCharPos++)
    {
       state = stateMachine [state] (outputString[currCharPos]);
    }
}
```