University of Manchester School of Computer Science

Bsc (Hons) Computer Science

Final year project

Writing a grammar & Parser for Blazon

Author:
Thomas Heyes

Supervisor:
Dr. Robert Stevens

April 30, 2013

Abstract

Blazon is the semi-formal language of family crest and heraldry, dating back to the twelfth century. Using a well structured grammar to describe a coat of arms in a top down approach the language provides a robust yet flexible way to define a textual description of what is naturally a very graphical subject. Using a test-driven development model I have produced a project which is capable of parsing a large subset of Blazon. Encompassing several fields of Computer Science ranging from parsing to HTML5 graphics the application provides a platform that demonstrates how modern concepts and technologies can be used to represent a subject that pre-dates them by centuries.

Firstly giving a brief background and description of the language of Blazon, this report goes onto describes both how the Blazon parsing application works as well as and how the project was implemented and tested. From a simple shield of a single colour through partitioning into sections and sub partitioning as well as covering different line-types before heading onto geometric charges, honourable charges and the rule of tincture before finally discussing semi-formal charges.

After thoroughly describing the language I go onto discuss the implementation of the project using test driven development. Producing lots of iterations increasing the functionality of the project gradually and performing regression testing to ensure the soundness of my code base. Initially starting with a couple of Python script based prototypes I describe how the project was iteratively built into a fully fledged web application over the course of the academic year. Given more time I would attempt to expand the project further into parsing and drawing a larger subset of Blazon with features such as Counter Charging and combining shields with Quartering.

Student: Thomas Heyes
Supervisor: Dr Robert Stevens
April 30, 2013

Contents

List of Figures

List of Tables

Chapter 1

Introduction

My project was to *Write a Grammar and Parser for Blazon.* Another student project by *Luke Torjussen* done the year before my own had attempted, very successfully, to produce an application that both parsed and drew representations of Blazoned coats of arms. This prior project used a parse generator to handle the grammar, lexing and parsing of the language. It was my objective to see if performing the parsing by hand in my own application could realise a more complete representation of Blazon.

Initially then my project was entirely based in tokenising, lexing, parsing and validating Blazon sentences. However my project grew later-on to also attempt to encompass producing a graphical representation of a parsed Blazon sentence as well as providing a plain English translation.

1.1 Aims

The aim of my project was to produce an application which upon receiving a Blazon sentence would firstly validate the sentence according to the rules of the Blazon language and then produce an English translation.

1.2 Achievable

1.3 Limitations

Chapter 2

What is Blazon?

Blazon is the language of heraldry and family crests, it dates back to the twelfth century and provides a strict set of rules about how to produce a coat of arms. There are several different versions of Blazon found around Europe however all follow the same behavioural rules regarding tinctures and charges. Most versions differ only in the set of tinctures and honourable ordinaries either having a more generous or conservative view on what is and isn't acceptable for example, African Blazon allows for an Orange coloured Tincture whilst English Blazon does not. For this project I focused on exclusively on a strict English Blazon.

Blazon is a powerful language for allowing limitless combinations and configurations of patterns and shapes to be *Blazoned* onto a shield in and recorded in a concise textual description.

What is impressive about the language is that it achieves this flexibility whilst reaming fairly formal and well defined, restricting the set of tinctures to total seven and maintaining a fairly low number of pre-defined honourable ordinaries.

Blazon, like any other language, has some unique terminology used to address certain aspects of heraldry. Anyone attempting utilize the language will need to familiarise themselves with this terminology.

2.1 The Seven Tinctures

The most fundamental elements of Blazon are the Tinctures. Tinctures are the set of colours allowed in coats of arms. English Blazon defines a set of seven tinctures and places them into to groups Metals and Colours.

Although at first this may seem overly restrictive Blazon overcomes having a limited set of valid tinctures by leaving interpretation of the tone and

The Seven Tinctures		
Tincture	Colour	Metal/Colour
Azure	Blue	Colour
Argent	Silver	Metal
Gules	Red	Colour
Or	Gold	Metal
Purpure	Purple	Colour
Sable	Black	Colour
Vert	Green	Colour

Table 2.1: Table of Tinctures found in English Blazon, the corresponding colours and whether each tincture is or isn't a metal.

shade of each Tincture's corresponding colour to the artist producing the shield. An Azure, blue, shield could be a light sky blue or a dark navy shade of blue depending upon the artists preference, as long as it is recognisably blue.

The Freedom of Interpretation is a great strength of Blazon vastly increases the different graphical variations of Blazoned shields without radically increasing the size of the language by exhaustively listing a set of valid tones and shades.

With regard to the two metallic Tinctures Or, gold, and Argent, silver, having freedom of interpretation allows for matt, non-metallic, colours to be placed onto a shield, although they will still behave as metal Tinctures. It is not uncommon to see yellow instead of gold and white instead of silver on many coats of arms.

2.2 Furs

Blazon incorporates several furs commonly used in coats of arms into the language. These behave in much the same way as tinctures but don't have the same metal or Colour property.

There are several pre-defined patterns for furs that are used directly instead of actual fur on a shield. These patters generally consist of a repeating pattern on-top of a background colour. Each fur has a unique pattern although several are very similar, some simply being the inverse of another.

The colours of Furs are pre-defined but can be explicitly stated as differing from the normal colours by stating the Tinctures to be used instead. For example for example Ermine coloured silver and black would be defined as *"Ermine Argent and Sable"*

2.3 Fields

A Field is simply an area on a shield. Initially a shield has one implicit Field, which is the entire area of that shield. Blazon allows for two operations on fields, a field can be Tinctured, with a Tincture or a Fur, or a field can be Partitioned. Tincturing a Field dictates that the whole area incorporated in that Field be filled in the colour of that Tincture. Partitioning I will cover in much more detail later on.

2.4 How to Blazon a Coat of Arms: Part One

I have now defined a large enough subset of Blazon for a couple of basic examples.

In each example we are implicitly provided with a single Field which encompasses the entire body of the shield. Then we Tincture that Field by providing a Tincture and we have successfully Blazoned a shield.

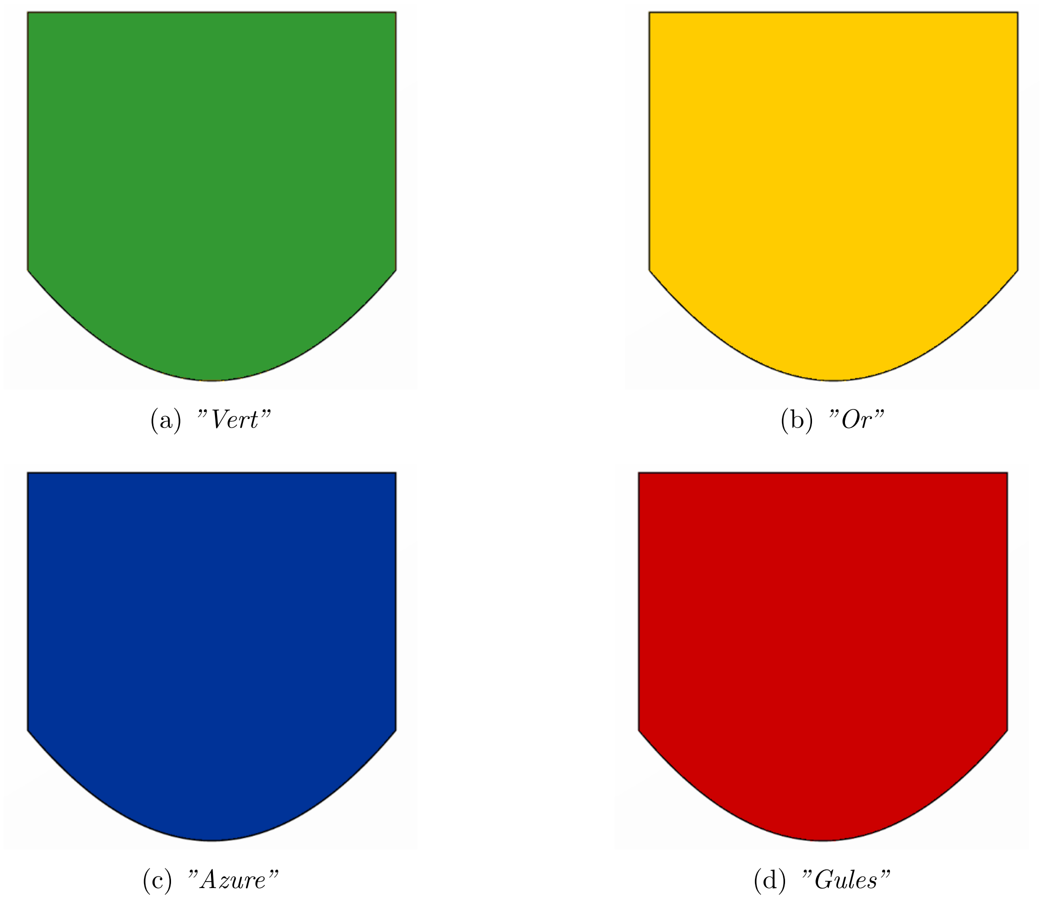

(a) *"Vert"* (b) *"Or"* (c) *"Azure"* (d) *"Gules"*

Figure 2.1: Basic Blazon examples.

Although the examples in Figure 2.1 are very basic each is a complete instance of a valid Blazoning of a shield.

2.5 Partitioning a Field

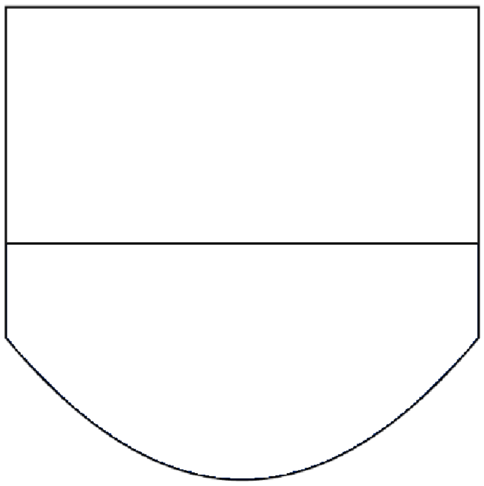
The Blazon I have defined so far is very limited, only allowing for single Tincture shields. The next natural area of the language to define is the operation of Partitioning a Field.

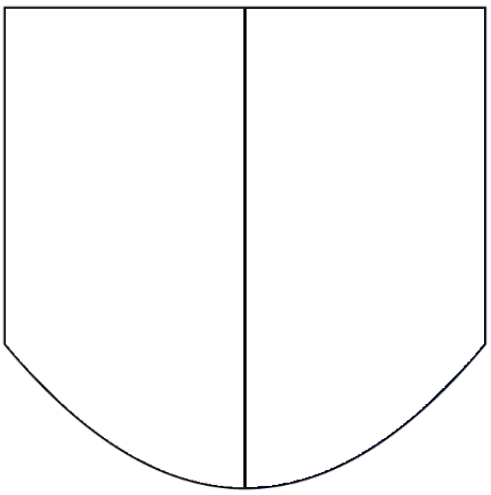
As stated previously a Field can be either Tinctured or Partitioned. To Partition a Field the key-word *"Per"* is used. It is obligatory that the word immediately after *"Per"* is a type of partition. Blazon has several pre-defined partitions ranging from the very simple *"Fess"* which divides a Field horizontally in half.

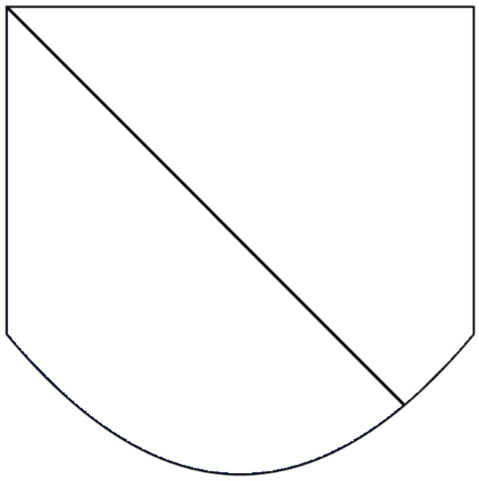
Partitioning a Field divides it up into several smaller fields the number and shape of which depend on the type of Partition used. After the Partition has been stated the Blazon sentence must go on to address the resulting new Fields.

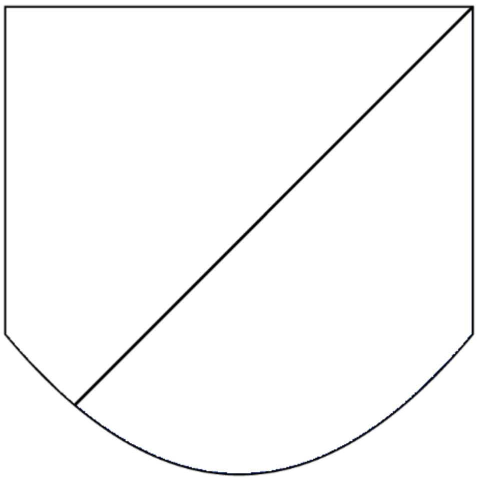
A shield is Implicitly Blazoned from top left to bottom right with the top most Field taking priority firstly and if two or more Fields are adjacent at the same height the left most takes priority.

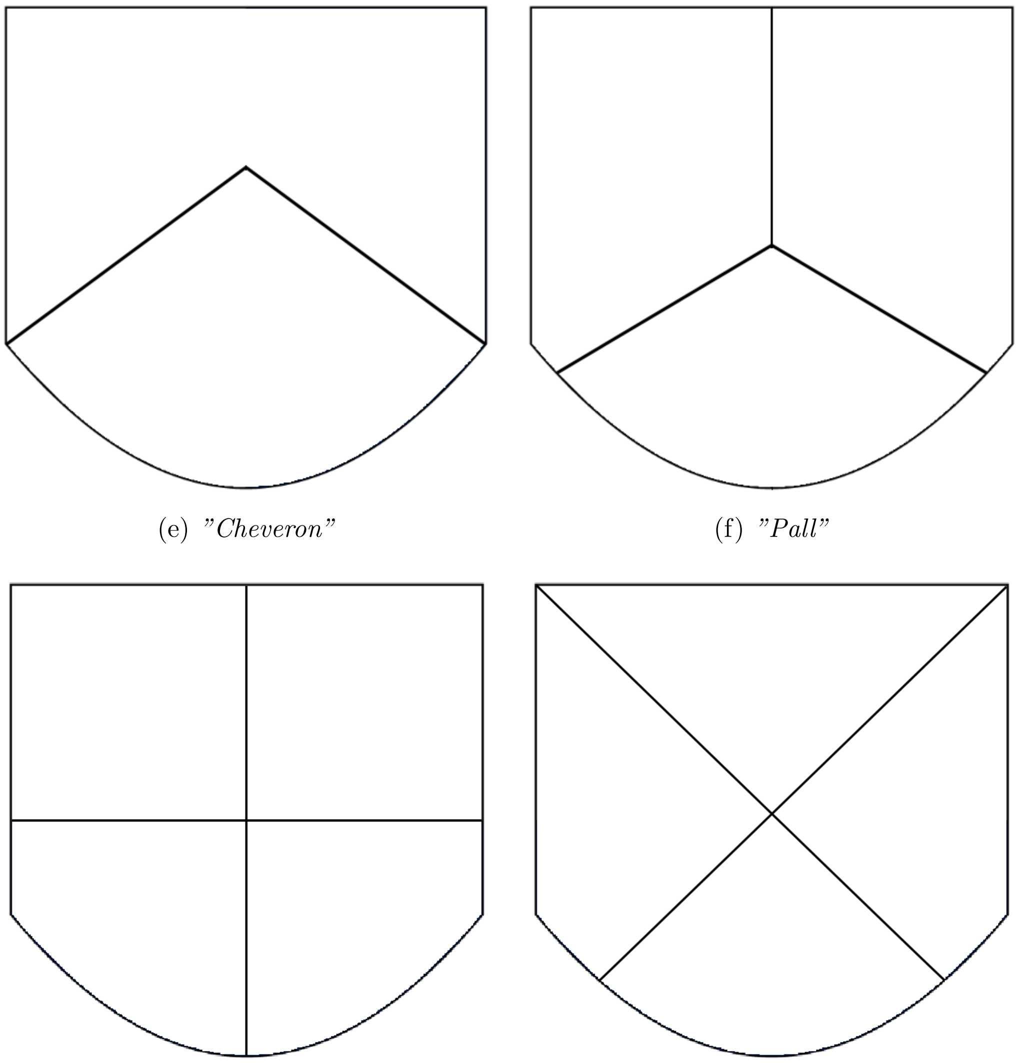
The Blazon sentence is only complete when all the Fields have been Tinctured. If a Blazon sentence Partitions a shield into two Fields and then provides only one Tincture that sentence is Invalid.


(a) *"Fess"*


(b) *"Pale"*


(c) *"Bend"*


(d) *"Bend Sinister"*


(e) *"Cheveron"* (f) *"Pall"*

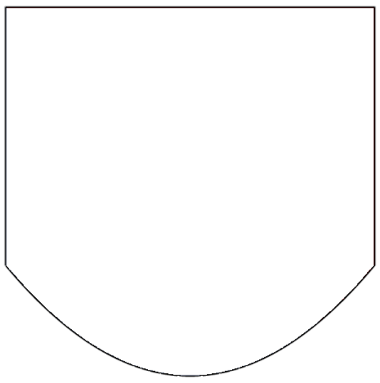
(g) *"Cross"* (h) *"Saltire"*

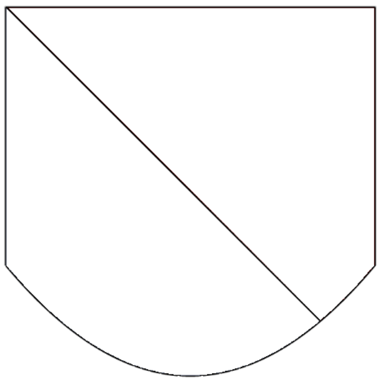
Figure 2.2: *"Valid Partitions of a Field"*

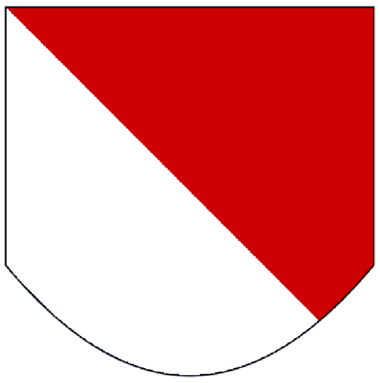
2.6 How to Blazon a Coat of Arms: Part Two

Partitioning is a very powerful aspect of Blazon and increases the number of possible shield designs immensely. A lot of very striking designs can be Blazoned onto a shield with very short Blazon sentences making use of Partitioning.

The Blazon sentence,*"Per Bend Gules and Azure"* Implicitly starts with a single Field which encompasses the entire body of the shield before partitioning that Field into two smaller Fields with the keyword *"Per"* declaring a partition followed by the word *"Bend"* which is a diagonal division of a field from top left to bottom right. The Blazon goes onto Tincture the two new fields with the two Tinctures *"Gules"* and *"Azure"* respectively, following Blazon's rule about evaluating the topmost and then leftmost field first the upper section of the shield is Tinctured *"Gules"* and then the lower half is Tinctured *"Azure"*. There is no more Blazon reaming in the sentence and there are also no empty fields upon the shield, therefore this is a valid Blazon sentence and a striking red and blue shield has been produced.


(a) *"A single empty Field."*


(b) *"The Field has been partitioned Per Bend"*


(c) *"The Topmost Field is Tinctured Gules"*

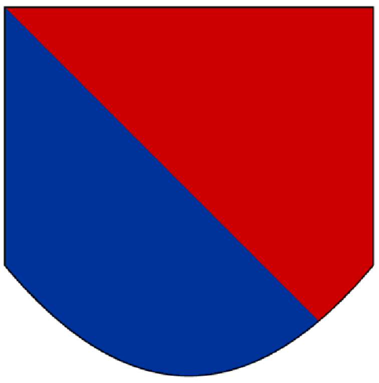
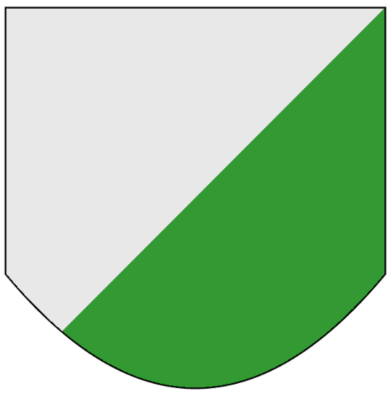

(d) *"The final Field is Tinctured Azure"*

Figure 2.3: *"Per Bend Gules and Azure"*.

Applying the same method as show above it is possible to validate the following Blazon sentences of similar complexity.


(a) *"Per Bend Sinister Argent and Vert."*

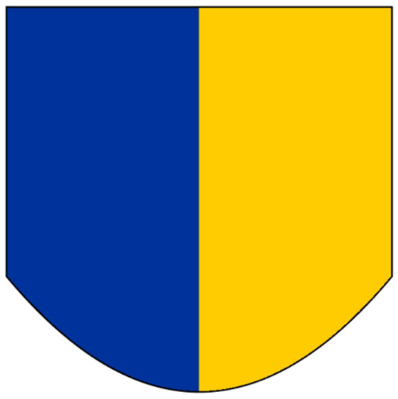

(b) *"Per Pale Azure and Or"*

Figure 2.4: *"Two more examples of valid Blazon sentences"*.

2.7 Sub-Partitioning

The process of Partitioning a field produces two or more smaller Fields. This allows for some very striking, though simple, designs. Blazon allows however for fields to be Sub-Partitioned. The new Fields produced after a Partitioning can themselves be Partitioned.

Considerably more advanced patterns can be achieved buy using Sub-Partitioning. The complexity is potentially infinite as there is no limit enforced by the language as to how many Partitions are allowed. It is rare to see a historical shield Sub-Partitioned more than three times. Sub-Partitioning makes use of exactly the same set of Partition types as regular Partitioning.

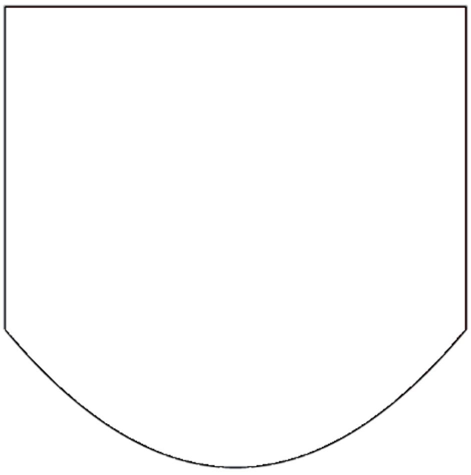
Sub-Partitioning is expressed in exactly the same way as partitioning. Once the initial field has been partitioned instead of providing a Tincture for one of the new fields the keyword *"Per"* is used to define a partition and then the type of partition is stated for example *"Fess"*. Then each of the new Fields need to be addressed either by being Tinctured or further partitioned.

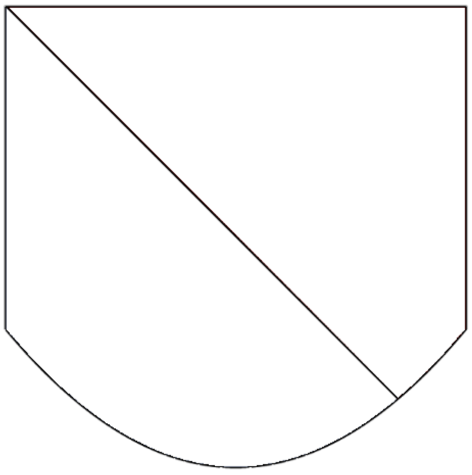
The new Fields created by the Partition fully evaluated before any other Fields on the shield are addressed. The new sub-fields are addressed according to the same rules present in regular Partitioning, namely the top most Fields take Priority then the left most, once they have all been evaluated the next field according to partitioning rules is addressed.

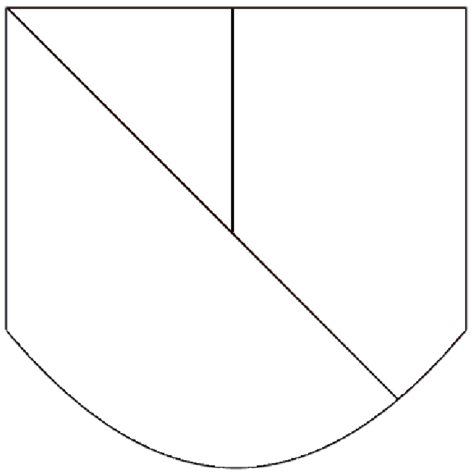
2.8 How to Blazon a Coat of Arms: Part Three

With Sub-Partitioning the set of valid Blazon sentences ceases to be finite, it is possible to repeatedly Partition a Field then Sub-Partition the new Sub-Fields and endlessly repeating this process. Very complex patterns can now be created with precisely defined Sub-Fields.

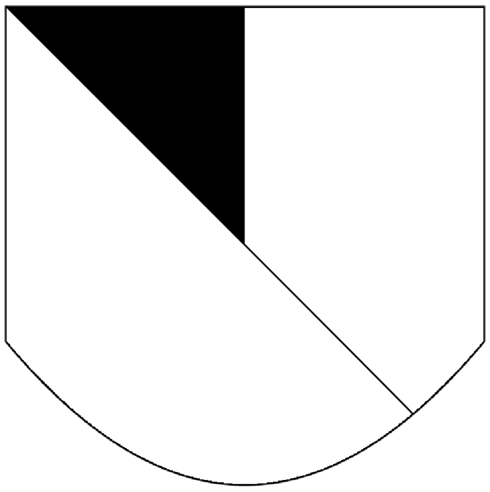
"Per Bend Per Pale Sable and Argent Per Fess Or and Gules" is an example a Blazon sentence which makes use of Sub-Partitioning. As before the sentence is addressed from left to right and there is an implicit Field over the entire body of the shield. The sentence is valid if there are as many Fields defined as there are instances of Tinctures in the sentence.


(a) *"A single empty Field."*

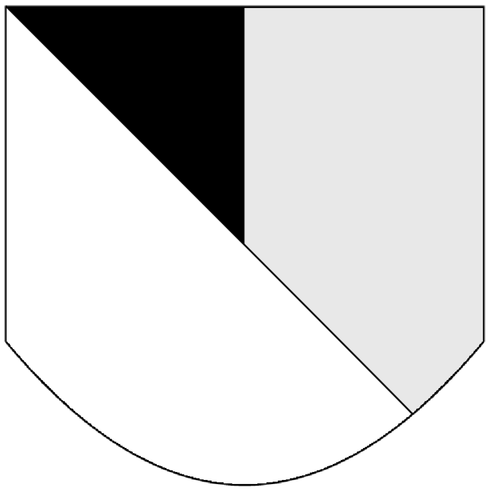

(b) *"The Field has been partitioned Per Bend"*



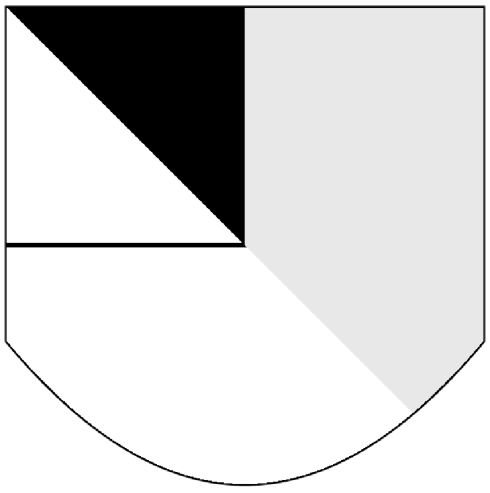
(c) *"The Topmost Field has then been Sub partitioned Pale"*



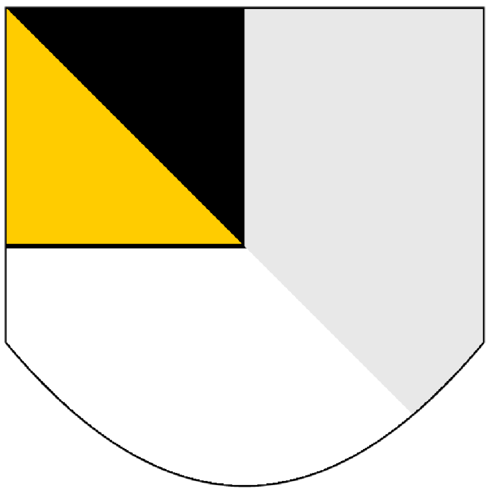
(d) *"The Top Left most Sub-Field is Tinctured Sable"*



(e) *"The remaining Field is Sub-Partitioned Fess"*



(f) *"The Top Left Most Sub-Field is Tinctured Or"*


(g) *"The remaining Sub-Field is Sub-Partitioned Fess"*

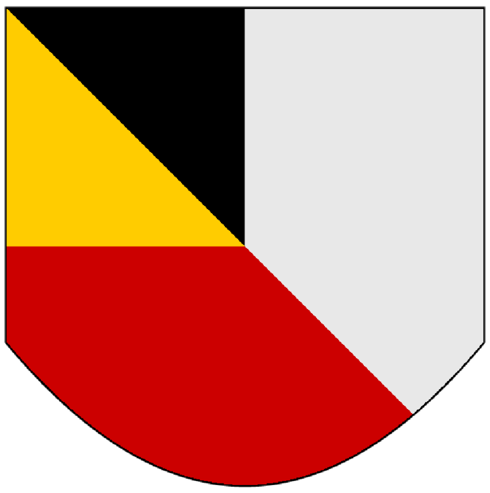

(h) *"The final Field is Tinctured Gules"*

Figure 2.5: *"Per Bend Per Pale Sable and Argent Per Fess Or and Gules"*.

2.9 Line Types

Blazon allows for Partitions to be patterned with different Line Types. The line division through a Field when partitioning is implicitly a straight line however there are a set of pre-defined Line Types which can be used instead.

A Lint Type is declared in Blazon simply by stating the name of the Line Type desired immediately after a partition. For example *Per Fess Embattled Argent and Sable* is the Blazon sentence for a Silver and Black shield divided horizontally with an *"Embattled"* line, see Figure7.4.

Line Types can be applied to Sub-Partitions and its possible to have multiple Line Types in a single Blazon sentence.

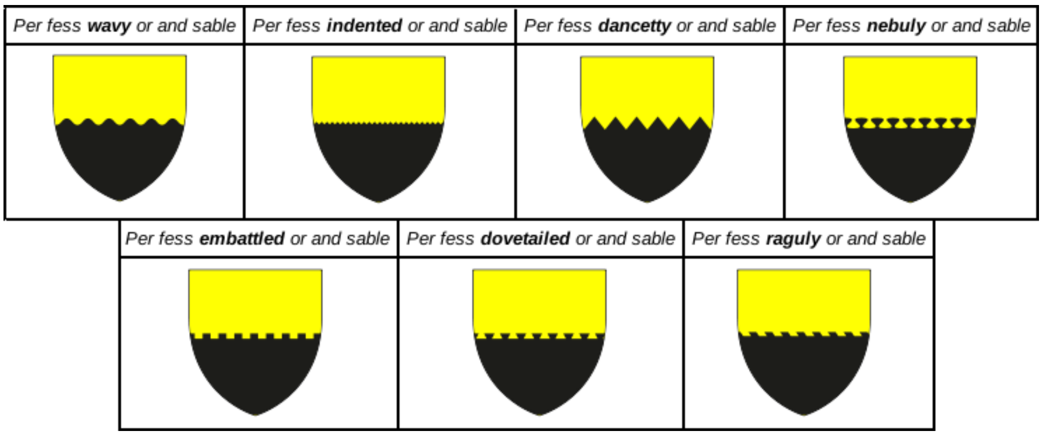

Per fess wavy or and sable
Per fess indented or and sable
Per fess dancetty or and sable
Per fess nebuly or and sable
Per fess embattled or and sable
Per fess dovetailed or and sable
Per fess raguly or and sable

Figure 2.6: Different line types valid in Blazon.[1]

2.10 Charges

Another powerful aspect of Blazon is the ability to place pictures, called Charges, onto a shield. Charges can be placed onto any Field that has been Tinctured. There are three subsets of Charge, the Honourable Charges, the Geometric Charges and Semi-formal Charges.

The Geometric Charges are the most simple, they are the set of basic shapes such as a square and a circle. The Honourable Charges are a set of predefined simple shapes some of which take after Partitions, such as *"Bend"*. The set of semi-formal charges contains everything that can be described textually, common examples are Lions and Eagles some royal Blazons have a crown as a Charge.

A Charge is declared in a Field by using a Quantifier immediately after the Field has been tinctured. The Quantifier is a pre-fix to the charge and determines how many instances of this Charge are present on this Field. For example the Sentence *"Vert a Crown Or"* Takes the implicit Field then Tinctures it *Vert* before Charging the Field with a Crown Tinctured *Or*, this would produce a green shield with a gold crown on it. Semi-formal Charges can be Tinctured *"Proper"* which is their natural colours. Even if a Charge is or a fictional creature it will have a proper colouring. Dragons are for example green when Tinctured *"Proper"*.

The size and position of a Charge is defined so that a Charge should take up as much space as possible without obscuring any other Charge or intersecting the perimeter of the Field it is being placed onto.

Its possible to have several instances of the same charge on a Field. There are common ways to position such groupings of Charges however there is freedom for the artist to arrange groups of Charges differently especially if the area doesn't lend itself to the traditional placement. A very wide but short Field would better suit its Charges being placed in a straight line rather than the usual grouping as long as each Charge is visible.

The prefix keyword can be a number or amount to define how many types of this Charge are present in this Field, *Argent three Delfs Sable* would produce a silver shield with three black squares on it in a triangular pattern, one each in the top corners and one centrally placed in toward the bottom.

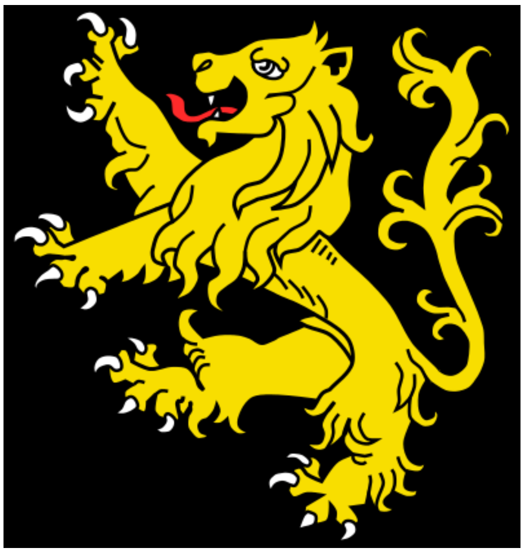
It is even possible to have multiple groupings of different Charges on a Field each Charge in the grouping is treated individually so that it is allowed to obscure any other Charge.

Keywords do exist for more specific positioning of Charges such as *"Beneath"* and *"Above"* these make it possible to position Charges relative to other Charges.

Finally, it is possible to place Charges upon other Charges. This can be done with the keywords *"in"* or *"upon"*. For example, *"Vert a Bend Azure upon a Chief Argent"* would produce a green shield with a silver bar along the top which has a blue diagonal bar on top of it.

2.11 Attitudes

Blazon allows semi-formal Charges to be given an *Attitude* to add further description to the Charge. This normally takes the form of an adjective applied as a suffix, one of the features inherited from French. For example a lion can be described as rampant or as passant both of which alter the pose the lion will be depicted in. A lion rampant is depicted as rearing up on its hind legs claws raised while a lion passant is standing horizontally with a single claw raised.


(a) *"A Lion Rampant.[4]"*

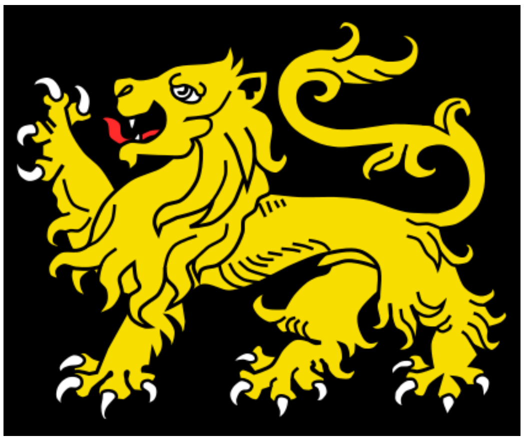

(b) *"A Lion Passant"[5]*

Figure 2.7: *"An example of applying attitudes to a charge"*.

2.12 The Rule of Tincture

One of the most important and widely followed rules of Blazon is the Rule of Tincture which states that *a colour may not be placed upon a colour nor a metal be placed upon a metal*[2, p.46]. This rule makes certain Tincture combinations of Charges and Fields invalid with each other. As stated above in Table 2.1, every tincture is either a Metal or a Colour in accordance with the Rule of Tincture, a Charge Tinctured with a Colour can only be placed upon a Field Tinctured with a Metal. Likewise, A Charge Tinctured with a Metal can only be placed upon a Fields Tinctured with a Colour.

Therefore, *"Azure a Cross Gules"* is an invalid Blazon sentence because both Azure and Gules are Colours and having a Colour Charged upon another Colour breaks the Rule of Tincture. The Rule also applies to Charges placed on Charges.

2.13 How to Blazon a Coat of Arms: Part Four

Charges are equally as important in Blazon as Partitioning, they allow the language a freedom to have any object placed upon them. With this extra functionality comes a slightly more complex terminology as described above with new keywords and the need to observe the Rule of Tincture.

Taking, *"Per Pale Azure a Cross Argent and Or a Saltire Gules"* as an example of a Blazon sentence which uses charges it is possible to demonstrate how Charges are used in Blazon.

Starting with the implicit initial Field the Blazon sentence starts *"Per Pale"* which Partitions the Field Per-wards, vertically. The left hand field is then addressed as it is the Top-Left most Field not yet Tinctured, the next word in the Sentence is a Tincture *"Azure"* which indicates this Field is to be blue. The next word in the sentence is *"a"* which is a quantifier for a single charge which the Sentence states is a *"Cross"* because the Charge is on a Field which has been Tinctured with a Colour, the Charge must be a Metal for the Blazon to be valid in this case the Tincture is *"Argent"* which is indeed a Metal.

As the next word of interest in the Blazon sentence is *"Or"* which as a Tincture and there have been no more charges declared we address the next Field so the right half of the shield should be gold in colour. Then there is another qualifier again its *"a"* indicating a single Charge which is stated as being a *"Saltire"* Tinctured *"Gules"* this produces a Colour Charge on a Metal Field and thus respects the Rule of Tincture.

There are no more words remaining in the Blazon sentence, all the Fields and Charges have been Tinctured and the Rule of Tincture has not been broken, therefore, *"Per Pale Azure a Cross Argent and Or a Saltire Gules"* is a valid Blazon sentence which contains two Fields each with a single Charge.

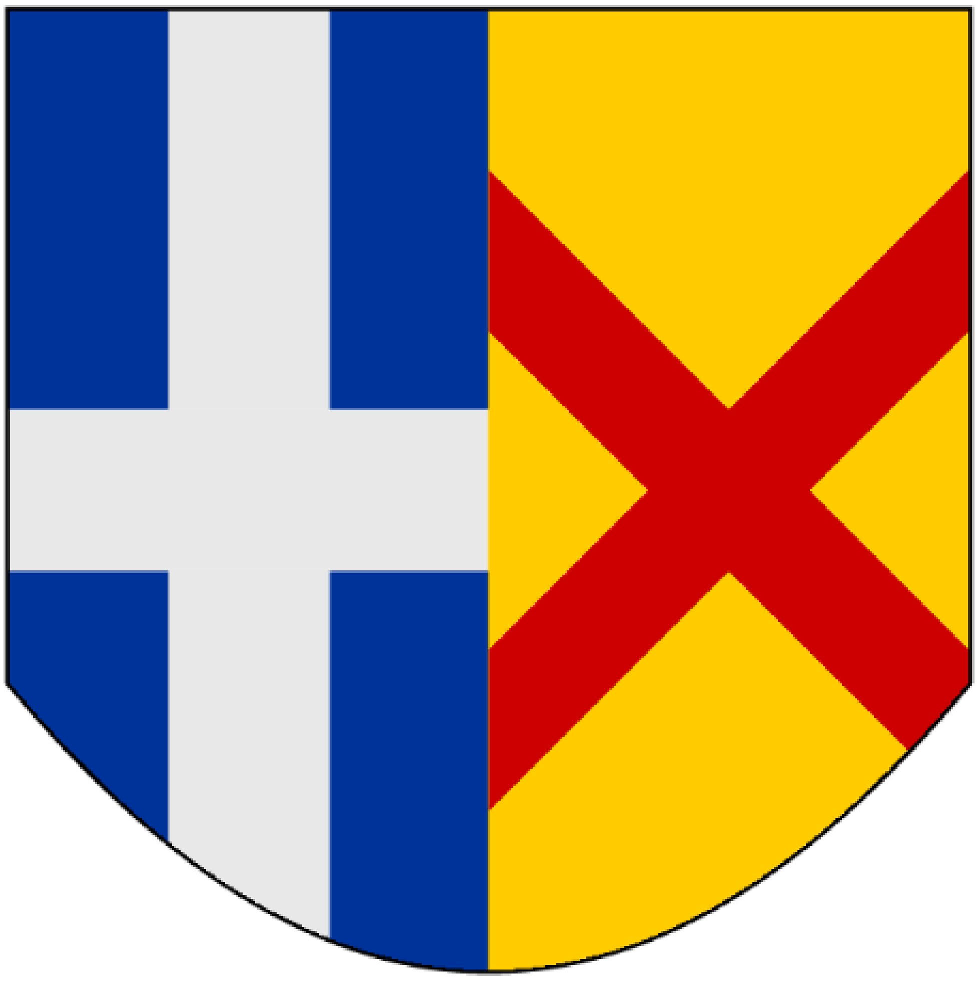


Figure 2.8: *"Per Pale Azure a Cross Argent and Or a Saltire Gules"*.

2.14 Counter-Charging

Blazon also provides functionality for positioning Charges across Fields; this is achieved though *Counter-Charging*. If a Blazon sentence has two adjacent Fields, then a Charge can be Counter-Charged across the two fields, this would split the charge down the line of Partition between the Fields before Tincturing each half of the Charge inversely to the Field it lies in. Counter-Charging is performed using the keywords *Counter Charged* as a suffix operator to a charge and must have two tinctured fields defined before it.

In the example shown in figure 2.9 , the Blazon sentence for the shield defines a Field Partitioned *"Per Pale"* then the two resulting Fields are Tinctured *"Argent"* and *"Gules"* then a Charge is defined *"a Bend"* which places a single diagonal bar upon the Field then the keywords *Counter Charged* are supplied instead of a Tincture which extends the bar across the two Fields and colours the section on the *Argent* Field in *Gules* and the section on the *Gules* Field in *Argent*.

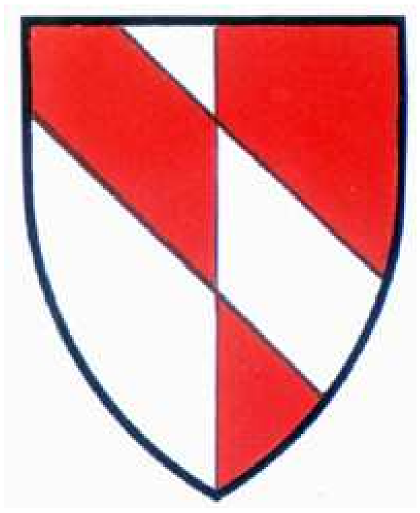


Figure 2.9: *"Per Pale Argent and Gules a Bend Counter Charged."[3]*

2.15 Directions and Sides

The Blazon language contains a set of words for describing positions and directions. These words are obviously useful for more accurately placing Charges on a Field. The top of the shield is refereed to as *Chief* and the bottom is refereed to as *Base*. The Left hand side of the shield, from the viewers perspective is called to as *Dexter* and the right hand side, again from the views perspective, is *Sinister*.

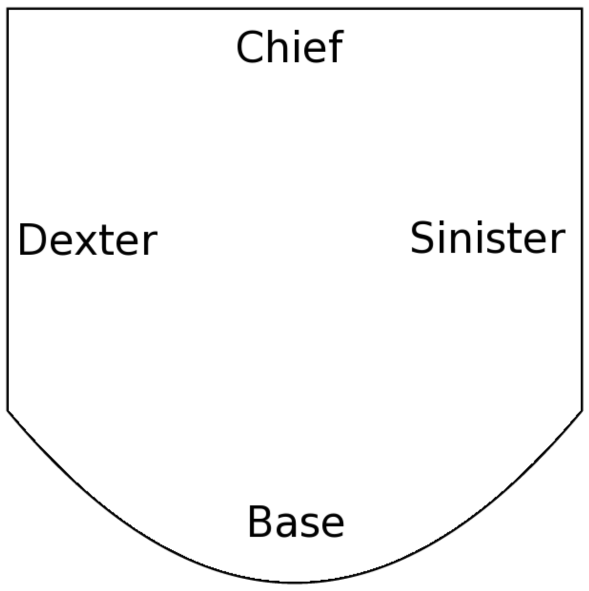


Figure 2.10: *The sides of the Field*

These keywords can be used to position Charges in a Field relative to each other. They can also be used to define direction, the most basic example of this is the Partition *"Bend Sinister"* which is a diagonal line from lower left to upper right. Semi-formal Charges can also be given a direction like so; *"A Purse Fesswise Argent Spilling Coins to Dexter Argent"* which would depicts a purse lying horizontally with coins to the left hand side, from the viewers perspective.

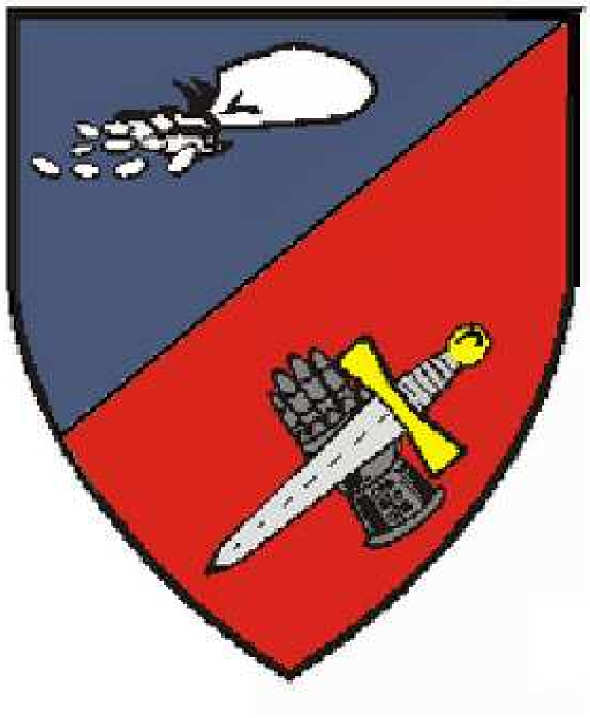


Figure 2.11: *Per Bend Sinister Azure A Purse Fesswise Argent Spilling Coins to Dexter Argent Gules a Gauntlet Bendwise appaumy (an attitude meaning open palmed) Argent Bendwise sinister inverted proper.*[6]

2.16 Overall

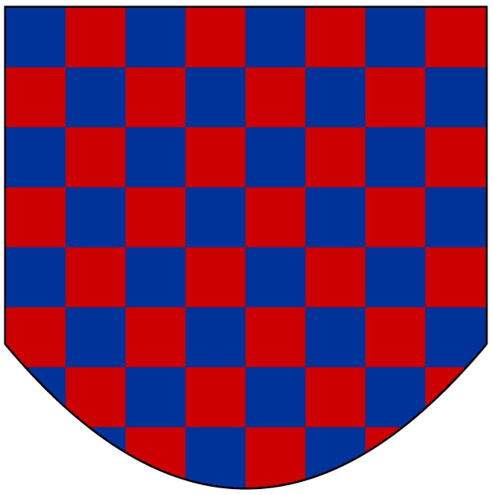
Blazon also encompasses a rudimentary system for layering. Charges can be placed on top of the entire shield as long as the don't break the Rule of Tincture of Obscure another Charge. This is achieved with the keyword *Overall* which occurs at the end of a blazon sentence, when all the Fields have been Tinctured, and is then followed by a Charge.

2.17 Variations

Finally Blazon has several pre-defined short hands for commonly used patterns known as variations. These patterns are all achievable through sub-partitioning but in a very verbose manor. *"Checky Argent and Gules"* produces a silver and red grid pattern which for all intents and purposes is the same as placing a large number of *Delfs* Tinctured Gules onto a Field

Tinctured Argent.

By default Blazon will produce the pattern in quantities of six. The number of repetitions can be stated by adding the suffix *"of"* and then providing a quantity.


(a) *"Checky of eight Azure and Gules"*.

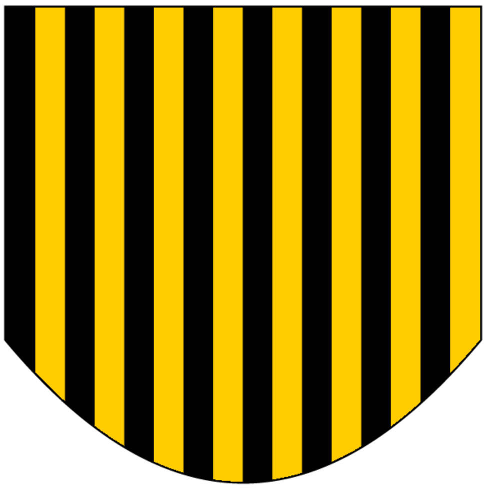

(b) *"Paly of sixteen Sable and Or"*

Figure 2.12: *Two examples of short hand being used.*

Chapter 3

Lexical Analysis

Before parsing a Lexical analysis must be performed upon the input. The aim of Lexical Analysis is present an input in a way that makes it easier to parse. This involves taking an input and splitting it into a series of tokens using keywords as identifiers.

3.1 What is Lexical Analysis?

Lexical Analysis is more concerned with classifying sections of input as instances of things than it is understanding them; as such there are generally several kind of tokens produced by a lexical analysis, determined by the context of the application. Tokens can range from being a single letter to being a series of words, again this is context dependant.

In traditional compilation all of the basic programming control statements would have their own Token; if, else, while, etc. Tokens provide a basic abstraction level as in the sense that you can have a token representing an instance of a Tincture but the actual data about the Tincture is irrelevant at this stage, although it must be stored for later.

3.2 Lexical Analysis of Blazon

Lexically Analysing Blazon sentences is fairly straightforward, this is due to the large number of pre-defined elements present in the language. All the Tinctures, Partitions and Line Types are pre-defined as well as all the Geometric Charges and Honourable ordinaries.

Blazon also heavily utilises keywords as prefixes, *"Per"* always indicates the next word is a partition and any quantifier indicates a charge.

A simple Blazon sentence such as *Per Bend Embattled Or and Argent* would be translated by lexical analysis into the following tokens *Partition, Line Type, Tincture, Tincture.*

Storing the data for each of the tokens is simply handled by each token being a separate instance of an object of that type. So upon encountering the word *"Gules"*, an instance of a Tincture object is created representing Gules.

For the sake of simplicity Geometric Charges and Ordinaries are to be considered in the same set of pre-defined Charges, whilst a Semi formal is to be treated as an edge case.

The only difficulty in lexing is dealing with Semi-Formal Charges. As they can be of any length and involve a large number of descriptive attitudes and positioning. A Semi Formal Charge declaration ends when either; the end of the sentence is reached, another quantifier and charge are declared or finally if two tinctures in a row are declared, one being for the charge and the other for the next field.

```
Lexically Analyse a given array of Strings which form a Blazon Sentence
$Words(anarrayofstringseachofwhichisawordinablazonsentence)$
$Tokens[]$
{For every word}
for $i = 0$; $i < Words.length$; $i++$ do
    if $Words[i] =$ "per" && $Words[i+1]\, is\, a\, Partition$ then
        Create a new instance of a Partition using $Words[i+1]$
        Add this instance of a Partition to the $Tokens$ Array
        increment $i$ by 1 to avoid lexing it twice.
    else if $Words[i-1]\, is\, a\, quantifier$ && $Words[i]\, is\, a\, Charge$ then
        Create a new instance of a Charge using $Words[i]$
        Add this instance of a Charge to the $Tokens$ Array
        {If a quantifier is not followed by a pre defined charge then it should
        be treated as a semi formal}
    else if $Words[i-1]\, is\, a\, quantifier$ then
        Create a new instance of a semi formal $Charge$
        Proceed through the array of string until the end of the charge dec-
        laration incrementing $i$ each time.
        Add this instance of a Charge to the $Tokens$ Array
    else if $Words[i]\, is\, a\, quantifier$ then
        Create a new instance of a Quantifier using $Words[i]$
        Add this instance of a Quantifier to the $Tokens$ Array
    else if $Words[i]\, is\, a\, LineType$ then
        Create a new instance of a LineType using $Words[i]$
        Add this instance of a LineType to the $Tokens$ Array
    else if $Words[i]\, is\, a\, Tincture$ then
        Create a new instance of a Tincture using $Words[i]$
        Add this instance of a Tincture to the $Tokens$ Array
    end if
end for
```

Figure 3.1: Pseudo code that produces a series of Tokens by performing Lexical analysis on a given array of Strings.

3.3 More Involved Lexing

While the above pseudo code does provide an adequate and valid Lexical Analysis of a Blazon sentence, it is quite naive.

It is not particularly necessary to have a operate token for each LineType and Quantifier as both only occur in relation to another kind of token so can not exist in isolation. Quantifiers only occur before a Charge so can be encompassed into an instance of a Charge and LineTypes only occur directly after a Partition or a Charge so can also be incorporated into the representation of those objects. It is also possible to reduce the occurrences of tinctures by wrapping Tinctures of Charges into the Charge object.

This would leave a system with only three different kinds of token which is considerably simpler than a system with five obviously it is *forty percent less complex.* This improvement isn't very hard to implement either although it does increase introduce a potential lookahead cost, where the lexer needs to check words further on in the sentence then that of the one currently being translated. Lookahead may resolve in such a way that doesn't result in anything being found in which case looking ahead was wasted computation. The maximum potential lookahead is the application is three words, when a quantifier is identified then the lexing function looks ahead for a Charge with a LineType and finally a Tincture.

```
1: Lexically Analyse a given array of Strings which form a Blazon Sentence
   {An array of strings each of which is a word in a blazon sentence}
2: $Words$
3: $Tokens[]$
   {For every word}
4: for $i = 0$; $i < Words.length$; $i++$ do
5:   if $Words[i]$ = "per" && $Words[i+1]$ $is\,a\,Partition$ then
6:     Create a new instance of a Partition using $Words[i+1]$
7:     Check for a Line Type and add to Partition instance
8:     Add this instance of a Partition to the $Tokens$ Array
9:     increment $i$ by 1 to avoid lexing it twice.
10:  else if $Words[i]$ $is\,a\,quantifier$ && $Words[i+1]$ $is\,a\,Charge$ then
11:    Create a new instance of a Charge using $Words[i+1]$
12:    Check for a LineType and add to Charge instance
13:    Find the tincture for this charge and add an Tincture object to the
       charge instance.
14:    Add this instance of a Charge to the $Tokens$ Array
       {If a quantifier is not followed by a pre defined charge then it should
       be treated as a semi formal}
15:  else if $Words[i-1]$ $is\,a\,quantifier$ then
16:    Create a new instance of a $Charge$
17:    Proceed through the array of string until the end of the charge dec-
       laration incrementing $i$ each time.
18:    Set the description of this charge to be the concatenation of all the
       words between the Quantifier and the ending Tincture.
19:    Add this instance of a Charge to the $Tokens$ Array
       {By looking for Tinctures last it ensures that Tinctures for Fields
       are never mistaken for Tinctures for Fields}
20:  else if $Words[i]$ $is\,a\,Tincture$ then
21:    Create a new instance of a Tincture using $Words[i]$
22:    Add this instance of a Tincture to the $Tokens$ Array
23:  end if
24: end for
```

Figure 3.2: Pseudo code for a slightly more complex lexical analysis that produces a simpler output with less tokens.

Although the algorithm is slightly more complex it simplifies parsing. By building line types and tinctures directly into the tokens it saves having to construct the more complicated data strictures later on.

Chapter 4

Defining a Grammar for Blazon

Now that the language of Blazon has been fully defined the task of Parsing it can begin. Parsing a language is a fairly complicated task however there are several standard tools found throughout the field that simplify the problem by breaking it down into smaller more manageable tasks. The first goal is to express Blazon as a Grammar.

4.1 What is a Grammar?

A grammar is best defined as a series of formal rules that define the syntax of a formal language. Blazon is only a semi-formal language as charges provide components that are not predefined, however they are only a sub set of the language and can be handled as an edge case which can be included into the grammar.

A sentence of a Language must conform to that Language's grammar. To this end a grammar can be used to both produce sentences for a language but can also be used to validate that sentences conform to a Language. This is exactly what is needed for parsing.

There are four parts to a grammar. Firstly every grammar has a set of terminal or atomic symbols which are the building blocks of the language. Secondly a grammar needs to have a set of non-terminal symbols which represent a series of terminal symbols. Thirdly a grammar will have a series of production rules which will take a terminal symbol and turn it into a either terminal or non-terminal symbols or a combination of both. Finally a grammar must have a defined non-terminal symbol as a start symbol.

There are two types of grammar, context free and context sensitive the difference between the two is in the production rules. A context sensitive grammar can have production rules where there are both terminal tokens and non-terminal tokens on both sides where context free grammars always uniquely have non-terminals on the left hand side of every production rule.

Grammars are also useful from an iterative development perspective as they can be built up over many iterations, which is exactly what I did.

4.2 Context free Grammars

Context free grammars are very simple but powerful tools for concise syntax definition. They form a top down hierarchy of non-terminal and terminal symbols which together can be used to generate every possible valid sentence in a language. Non-terminal symbols are symbols that have still to be fully evaluated whilst terminal symbols are atomic and can not be evaluated further.

Sentences are crafted by defining a series of production rules for the language. In a context free grammar a production rule takes a non-terminal symbol and translates it into a different symbol or series of symbols which may be a combination of terminal or non-terminal.

A Context has a designated start non-terminal symbol which provides the highest level of abstraction. The start symbol is evaluated by translating it using any of the production rules that take the start symbol. The out put from the production rule now needs to be evaluated. This is done by taking the left most, head, non-terminal symbol, using a production rule to evaluate it and then repeating until no non-terminal symbols remain. Non-terminal symbols allow for a basic level of abstraction in a grammar as they may evaluate into any number of possible other symbols defined by the production rules of the language. The start symbol will be the most abstract and the terminal symbols will be well defined instances.

4.2.1 An Example Context Free Grammar

To demonstrate the power of a context free grammar an exaple will be to generate a sentence of a language using a trivial grammar. The example will define a Context Free Grammar which will produce sentences for the language of Meals.

$$Meal \rightarrow Food + Drink$$

$$Food \rightarrow Steak \,|\, Potato \,|\, Fish \,|\, Salad$$

$$Drink \rightarrow Tea \,|\, Wine$$

Figure 4.1: Context Free Grammar of a Meal

The start symbol for this grammar is *Meal.* There are three non-terminal symbols in the grammar, Meal, the start symbol, Food and Drink. The | symbol is used as an exclusive or so that multiple production rules can be compressed. Drink may evaluate to Either Tea or Wine.

An example of producing a sentence of the Meal language:

Starting with the start symbol:

$Meal$

Using the production rule for Meal:

$Meal \rightarrow Food + Drink$

Results in:

$Food + Drink$

Evaluating the left most non-terminal using the production rule for *Food* which results in *Steak*:

$Food \rightarrow Steak$

Results in:

$Steak + Drink$

Finally evaluating *Drink* using the production rule resulting in *Wine*:

$Drink \rightarrow Wine$

Results in:

$Steak + Wine$

As there are no more non-terminal symbols remaining the production is complete.

Figure 4.2: Producing a Meal (easier than cooking)

4.3 Context Free Blazon

Obviously Blazon is a considerably more complex language than Meal. As such it requires a larger grammar to fully express it.

The grammar's start symbol is *Field* which represents the single Field that encompass the entire shield. The grammar needs production rules that allow a Field to be either Partitioned, with or without a line type, producing a Partition as well as a number of fields or Tinctured which produces a Tincture.

Partitions are all pre-defined to produce a set number of sub-fields depending on the number produced a partition can be evaluated into any of the appropriate terminals.

Tinctures can be evaluated into any of the valid Tinctures defined in Blazon which are all terminal symbols.

A Field can also evaluate into a Tincture and a Quantifier, which in turn evaluates into a Charge. It is possible to have more than one charge per field so a production rule is defined that evaluates a Quantifier into a Charge and another Quantifier, for the next charge. This can be used repeatedly to generate any number of charges.

Charges can belong into one of three categories, Ordinaries, Geometrics or semi formal. The Geometric charges are all pre-defined as are the Ordinaries. Semi-formal charges are the exception in that they can not be pre-defined exhaustively. However they follow the same syntactic pattern as regular charges defining the image first and ending in a tincture.

Line types are all predefined so evaluate into terminal symbols.

Blazon as a context free grammar

$Field \rightarrow PartitionOfTwo + LineType + Field + Field$

$Field \rightarrow PartitionOfThree + LineType + Field + Field + Field$

$Field \rightarrow PartitionOfFour + LineType + Field + Field + Field + Field$

$Field \rightarrow PartitionOfTwo + Field + Field$

$Field \rightarrow PartitionOfThree + Field + Field + Field$

$Field \rightarrow PartitionOfFour + Field + Field + Field + Field$

$Field \rightarrow Tincture$

$Field \rightarrow Tincture + Quantifier$

$Quantifier \rightarrow Charge$

$Quantifier \rightarrow Charge + Quantifier$

$Charge \rightarrow Ordinary + Tincture$

$Charge \rightarrow Geometric + Tincture$

$Charge \rightarrow Semi - formal + Tincture$

$Ordinary \rightarrow Fess|Bar|Bend|BendSinister|Pale|Chief$

$Ordinary \rightarrow Base|Cross|Saltire|Chevron$

$Geometric \rightarrow Delf|Roudle$

$Tincture \rightarrow Azure|Gules|Vert|Sable|Argent|Purpure|Or$

$PartitionOfTwo \rightarrow Pale|Fess|Bend|BendSinister|Chevron$

$PartitionOfThree \rightarrow Pall$

$PartitionOfFour \rightarrow Cross|Saltire$

$LineType \rightarrow Embattled|Wavy|Indented|Dancetty|Nebuly|Dovetailed$

$SemiFormal \rightarrow ???$

Figure 4.3: Blazon as a Context Free Grammar

Chapter 5

Parsing

After Lexical Analysis is complete and the input string has been tokenised the next step is to generate a parse tree. Parsers produce a data structure that takes into account all the details of the language defied in its grammar and also attempt to perform error handing.

5.1 Building Parse Trees

A parser takes the output from lexical analysis and turns it into a tree data structure. This tree structure enforces properties not apparent from just a linear sequence of tokens such as associativity. The structure also validates the input by checking it against the grammar for the language.

One of the features of a user friendly parser is reporting errors that the user has made in the input to the application to assist in fixing the input.

5.2 Parsing Blazon

Parsing Blazon involves taking the tokens generated form Lexical analysis and producing a well formed data structure that checks whether the input conforms to the defied grammar, figure 4.3, or not and attempts to report the reason behind why the input may be erroneous.

Blazon lends it self very well to a top down, left to right parsing method because of the way the language is defined. Fields are defined and Tinctured from the top-left most point downwards and mirroring this approach in parsing makes for a nice parallel.

The output from the lexical analysis is of a fairly high level because of the more advanced lexing approach taken which wrapped Line Types, Quantifiers and Tinctures into other objects when appropriate.

To build the data structure itself each of the objects to be instantiated have inbuilt class variables to allows them to act as nodes in a tree.

Partitions all have an array, the size of which is determined by the number of fields to be created for the particular type of partition. Tinctures have an array of Charges so that they can have multiple charges placed upon them.

As Blazon sentences all implicitly start with an empty field that encompass the entire shied this is where the parser and parse tree will start. In the implementation the implicit field is represented by a partition which produces a single field, an *Escutcheon*.

The parser then takes the first token initially a field, according to the grammar the only valid operations that can be performed upon a field are Tincturing and Partitioning, therefore the parser checks whether this token is either a Tincture or a Partition and if the token is either of them it is added to the initial field accordingly.

This process is repeated until either there are no more tokens left to parse, no more space in the tree structure exists, upon a valid Blazon sentence, both.

5.3 An Example of Parsing Blazon

The following demonstrates the parsing of the Blazon sentence *Per Bend Azure and Or a Cross Vert.*

The tokens generated by Lexical analysis would be, *Partition (Bend),*

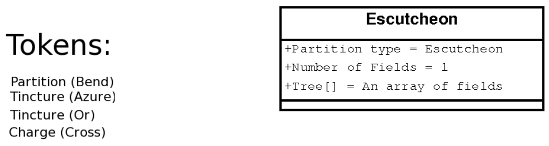


Figure 5.1: *"The root of the tree is the implicit Field."*

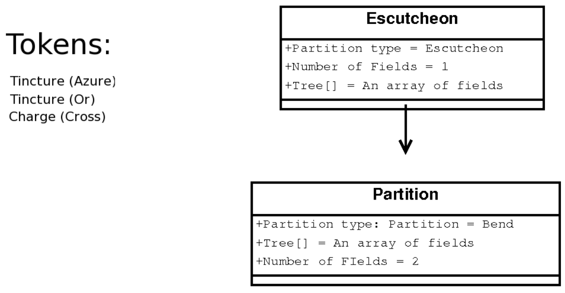
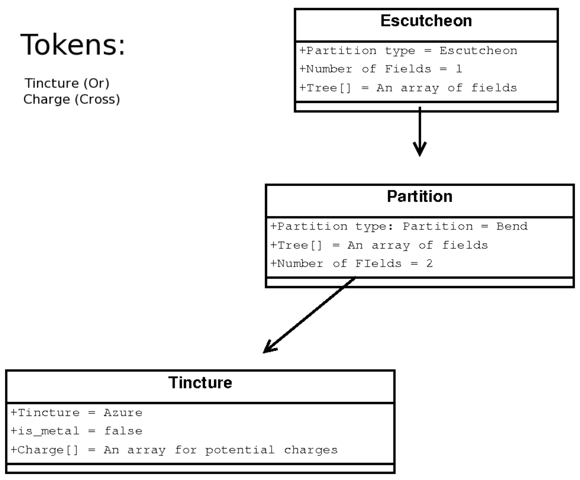
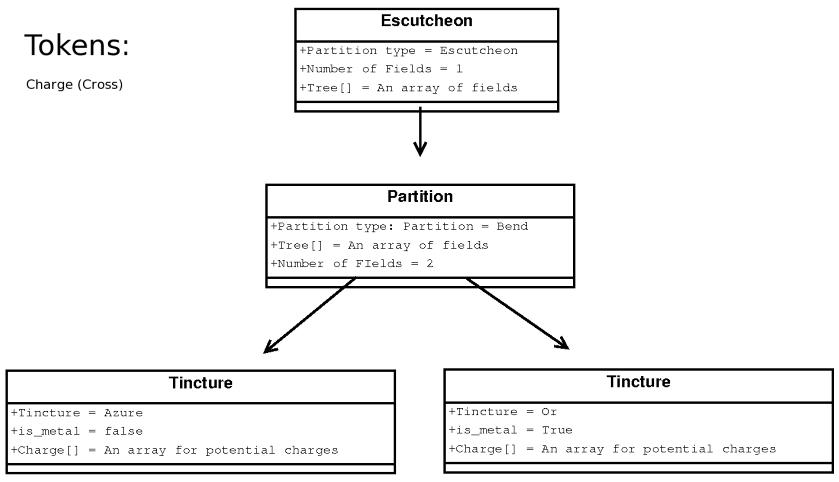

Tokens:
Tincture (Azure)
Tincture (Or)
Charge (Cross)
Escutcheon
+Partition type = Escutcheon
+Number of Fields = 1
+Tree[] = An array of fields
Partition
+Partition type: Partition = Bend
+Tree[] = An array of fields
+Number of FIelds = 2

Figure 5.2: *"The first token is checked against the grammar then added to the tree array of the initial field."*



Tokens:
Tincture (Or)
Charge (Cross)
Escutcheon
+Partition type = Escutcheon
+Number of Fields = 1
+Tree[] = An array of fields
Partition
+Partition type: Partition = Bend
+Tree[] = An array of fields
+Number of FIelds = 2
Tincture
+Tincture = Azure
+is_metal = false
+Charge[] = An array for potential charges

Figure 5.3: *"The next token is a Tincture so the first element of the Bend's tree array is assigned to this Tincture"*



Tokens:
Charge (Cross)
Escutcheon
+Partition type = Escutcheon
+Number of Fields = 1
+Tree[] = An array of fields
Partition
+Partition type: Partition = Bend
+Tree[] = An array of fields
+Number of FIelds = 2
Tincture
+Tincture = Azure
+is_metal = false
+Charge[] = An array for potential charges
Tincture
+Tincture = Or
+is_metal = True
+Charge[] = An array for potential charges

Figure 5.4: *"The next token is another Tincture so the second element in the Bend's tree array is assigned to this Tincture."*

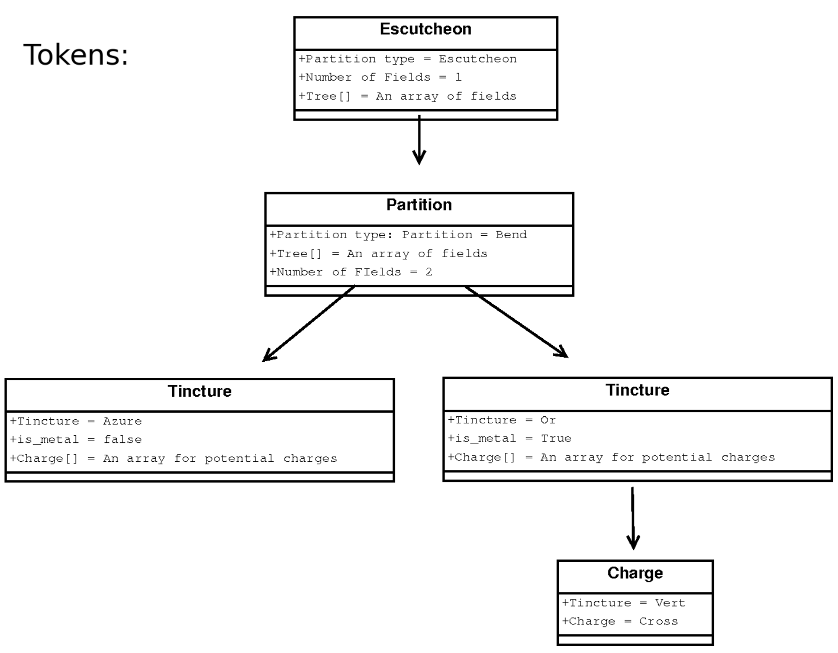

Tokens:
Escutcheon
+Partition type = Escutcheon
+Number of Fields = 1
+Tree[] = An array of fields
Partition
+Partition type: Partition = Bend
+Tree[] = An array of fields
+Number of FIelds = 2
Tincture
+Tincture = Azure
+is_metal = false
+Charge[] = An array for potential charges
Tincture
+Tincture = Or
+is_metal = True
+Charge[] = An array for potential charges
Charge
+Tincture = Vert
+Charge = Cross

Figure 5.5: *"The final token is a Charge as the last token was a Tincture this is a valid token. The Charge is assigned to the first element of the Or's charge array. As there are no more tokens and no more empty fields this is a valid Blazon sentence and has finished being Parsed."*

5.4 Error Reporting

If an errors is detected whilst building the Parse tree the Blazon sentence is invalid. However the end user would benefit greatly if the application could evaluate further as to why the input was erroneous. Depending upon where in the parse function the error is detected will change what potential errors could have occurred. The more error reporting that the parser performs the easier it is for the user to correct their mistake.

The obvious error to address is that of an incomplete Blazon sentence. If there are no more tokens but the tree has empty nodes in it then the Blazon sentence is invalid because at least one field has yet to be tinctured. If the inverse is true and there is no space in the tree for the next Token then too many fields have been defined.

The rule of tincture is also enforceable during parsing by checking the parent node's Tincture type against the potential Charge's Tincture. It is also possible to check that a charge is not placed upon an empty field.

The most appropriate way to deliver feedback to the user regarding an error is in such a way that they must give it attention. The application utilises JavaScript alerts for error reporting as the user must acknowledge them before continuing as they are modal, they hold the focus of the browser until acknowledged.

5.5 A Parsing Algorithm

Pseudo code for implementation of the parsing function used in the web application is given below, in Figure 5.6. As the implementation was written in JavaScript arrays are objects and upon removing the first element in an array the index of reaming elements are all decremented by one implicitly.

```
A recursive function that builds a parse tree from a series of Tokens As input arguments it takes a reference to an array of Tokens provided by Lexical Analysis and the Current node in the Tree, initially the Root node.
$Tokens$
$CurrentNode$
while While there are still empty cells in the current node's tree array do
    if $Tokens$ is empty then
        return false {as the tree is still being evaluated but no tokens remain there are empty sections remaining on the shield and the Blazon sentence is invalid.}
    else if $Tokens[0]$ is a Partition then
        Push $Tokens[0]$ into the next empty cell of $CurrentNode$'s tree array
        Remove the element at $Tokens[0]$ as it has now been parsed
        Recur passing the $Token$ just placed in $CurrentNode$'s tree array as the new $CurrentNode$ and a reference to $Tokens$
    else if $Tokens[0]$ is a Tincture then
        Remove the current element at $Tokens[0]$ and place it into the next empty cell in the $CurrentNodes$'s tree array.
        {Charges can only be placed immediately after a Tincture so can only be valid tokens if found in this control sequence}
        while $Tokens[0]$ is a Charge do
            if The Tincture of $Tokens[0]$ is a metal && The Tincture found was a metal then
                Rule of Tincture broken
                return false
            else if The Tincture of $Tokens[0]$ is a colour && The Tincture found was a colour then
                Rule of Tincture broken
                return false
            else
                Remove this Charge from $Tokens[0]$ and add it to the Tincture's Charge Array
            end if
        end while
        {$Tokens[0]$ is a Charge}
    else
        Charges can only be placed immediately after a Tincture which is handled in the above control sequence.
        return false
    end if
    return true
end while
```

Figure 5.6: Pseudo code for Parsing Blazon.

5.6 Tree Navigation and Results

Once the parse tree has been constructed a English description of the shield that was described by the Blazon sentence can be output. All of the main data structures contain an English description of what they represent in the Blazon. Navigating through the tree in the correct order and queering all of the nodes in order of being visited is all that needs to be done. The tree was built from left to right so needs to be navigated in that order as well.

The English output from the Blazon Sentence presented in 5.5 generated is; *"A shield split diagonally from upper left to lower right , coloured blue, coloured gold / yellow with 1 green solid + shape"*. Which, although a little verbose, is a fairly accurate description of the shield from 5.7.

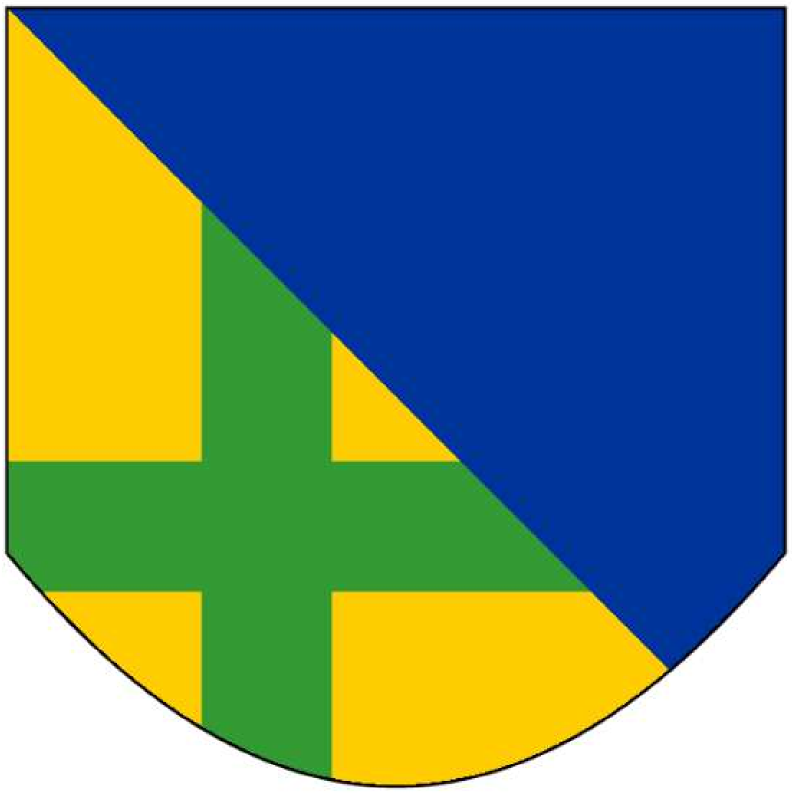


Figure 5.7: *Per Bend Azure and Or a Cross Vert.*

Chapter 6

Graphical Representations

After parsing the Blazon sentence into a parse tree the application attempts to draw a visual representation of the shield. This is done via the use of HTML5's Canvas element and JavaScript.

Producing the Graphical Depiction of the Blazon was less important from a functionality standpoint than correct parsing of sentences but does make for a much more interesting application for an end user.

6.1 Adding a Graphical Description to Data Structures

The logical way to draw the shield was to approach the task in the same way as the textual description is handled. Each of the data structures acting as nodes in the parse tree were expanded to implement a draw function which was called on each node in the parse tree as it was navigated.

This approach provided several advantages. Firstly it utilised the parse tree and data structures which were all ready implemented, working and fully tested. Secondly it provided a way to continue working in iterative stages like the rest of the application and thirdly if it provided the potential for very generic drawing functions that would provide a lot of reuse.

Once again the most challenging aspect in the implementation were the semi formal charges. The decision was made to ask the user to provide an image of the semi-formal charge they wanted to define. This image would then be loaded directly onto the canvas in the appropriate place.

6.2 Drawing a Shield

The first stage in implementing a graphical front end to the application was to define a way of drawing a shield. this was achieved by utilising the Canvas element's path functions.

The equation for the curve of the shield was:

$$y = 625 - x^2/500$$

Figure 6.1: For x =-300 through to x =+300

One of the quirks of HTML5's Canvas is that the y axis is inverted. The top left corner of the Canvas is (0,0). Which is why there is a negative constant in the parabola defined in 6.1. The rest of the shield is defined as a path from the end of the parabola in a rectangle back to the other edge of the parabola.

The whole area is now clipped which is another function provided by Canvas that ensures no drawing can occur outside of the current path, the shield.

6.3 Drawing Tinctures

One the actual body of the shield was drawn the next step was to implement the draw functions of Tinctures as they are the most basic elements of Blazon. It would be very hard to test either Charges or Line Types without Tinctures being defined before hand.

Tincture objects all needed to have hex colours defined for them which was a simple addition to the constructor. The draw function was then defined as a generic function that took a path on the Canvas and used the given Canvas function *fill* to colour the bounded area in the colour of the hex colour.

6.4 Partitioning Fields

Successfully partitioning fields in the graphical representation was one of the more challenging aspects of the project for several reasons.

Any field can be partitioned by any partition therefore all the partition calculations need to be completely generic so that they can be used in all the possible situations that may arise. This causers a large number of edge cases to occur.

Every field needs to have consistent winding, the order the points that compose the field are joined together, so that the top left ordering of Blazon isn't lost.

6.5 Implementing Field Partitioning

What needs to be achieve is a system that takes the boundaries of a field and a partition and turns this into a series of new boundaries depending upon the partition given.

The algorithm I devised for partitioning a field takes the boundaries of the current field and places the current partition onto it. The algorithm then determines all the points of intersection between the field boundaries and the partition.

The points of intersection need to be grouped together in a way to generate new boundaries of the sub fields formed from the partition.

If a point of intersection lies between two corner points of the boundary then it becomes a corner of the new fields. If an intersection occurs upon a corner of the current boundaries then it is present in both sets of boundaries generated for the new field.

A function that takes the boundary of the current field, the lines of partition determined by the current partition and the number of sub fields to be produced:

```
$2dPoint[]\, Boundary$
$2dPoint[]\, lines\, of\, Partition$
$int\, NumberOfSubFields$
{Create a two dimensional array, each element will hold a 2dPoint[] for the boundaries of a new sub-field}
$NewFields = newArray$
for Every new sub-field, $NumberOfSubFields$ do
  $NewFields[] = new2dPoint[]$
end for
```

```
$CurrentFieldIndex = 0$
**for** Every point in $Boundary$ **do**
  $NextPoint =$ the next point in $Boundary$
  **if** There an intersect between the current point and the next point **then**
    **if** The point of intersect lies on the current point in the boundary **then**
      $NewFields[CurrentFieldIndex] =$ the point of intersect {Add the point of intersection to the current sub-field}
      $CurrentFieldIndex ++$
      $CurrentFieldIndex\% = NumberOfSubFields${Instead of going out of bounds go back to zero}
      $NewFields[CurrentFieldIndex] =$ the point of intersect {Add the point to the next sub-field}
    **else if** The point of interest lies on $NextPoint$ **then**
      Ignore and deal with next loop iteration. {The intersect isn't on a corner}
    **else**
      $NewFields[CurrentFieldIndex] =$ the current point in $Boundary$ {Add the current boundary point to the current sub-field}
      $NewFields[CurrentFieldIndex] =$ the point of intersect {Add the point of intersection to the current sub-field}
      $CurrentFieldIndex ++$
      $CurrentFieldIndex\% = NumberOfSubFields${Instead of going out of bounds go back to zero}
      $NewFields[CurrentFieldIndex] =$ the point of intersect {Add the of intersection point to the next sub-field}
    **end if**
  **else**
    $NewFields[CurrentFieldIndex] =$ the current point in $Boundary$ {Add the current boundary point to the current sub-field} {no intersection succoured}
  **end if**
**end for**
**for** Every element if $NewFields$ **do**
  Set Winding {The boundaries must be defined so that the top left most point is the first in the array or the ordering of the fields becomes skewed}
  return $NewFields$
**end for**
```

Figure 6.2: Pseudo code dividing a field into a number of sub-fields based upon a given partition.

6.6 A Visualisation

What the algorithm in figure 6.2 is doing is dividing the field into a number of sub-fields. This involves finding points of intersection between the partition and the field parameter. A check needs to be made between each adjacent point of the boundary as to whether there is a point of intersection with the partition between them, if there is the the first point is assigned to the first sub-field and the second point to the second boundary with the point of intersection assigned to both.

There is an edge case where the point of intersection lies directly on one of the boundary points, in this case the point must belong to both sub-fields. A visual example is provided in figure 6.3.

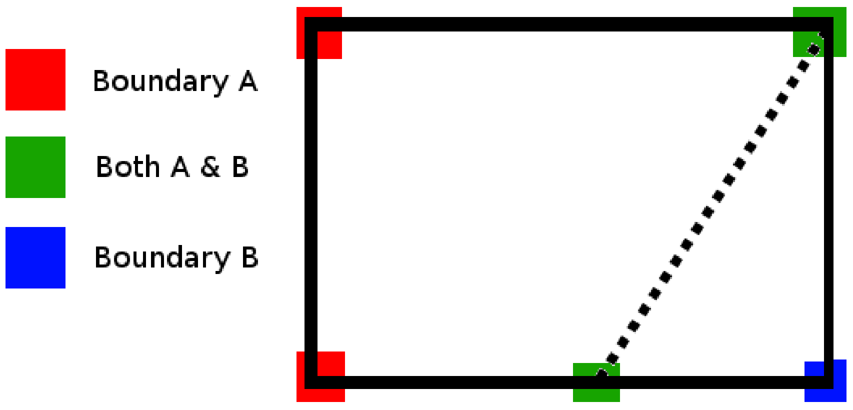


Figure 6.3: UML description of a Tincture.

6.7 Individual Partitions

The only part section of graphically representing partitioning is defining how each partition is defined before being passed to the function in figure 6.2. Each partition is obviously different graphically and generally defining the line of intersection across a field was not too complex.

Bare in mind that these *lines* are not drawn but are merely used to define paths and that the points of intersection are used to determine boundaries so defining a line across the entire canvas is fine as the excess is discarded.

6.7.1 Fess

The line of intersection is defined across the entire canvas horizontally at the median Y axis value for the field.

6.7.2 Pall

The line of intersection is defined across the entire canvas vertically at the median X axis value for the field.

6.7.3 Bend

If the field is rectangular the line is simply defied to connect the top left to bottom right corners else the line of intersection is defined across the entire canvas at a forty five degree decline in such a way that the line intersects the median Y axis value for the field.

6.7.4 Bend Sinister

Exactly the same as above but at an incline instead of a decline.

6.7.5 Cross

A concatenation of Fess and Pall. The middle X and Y values are calculated for the field and then used for both Fess and Pall partitions.

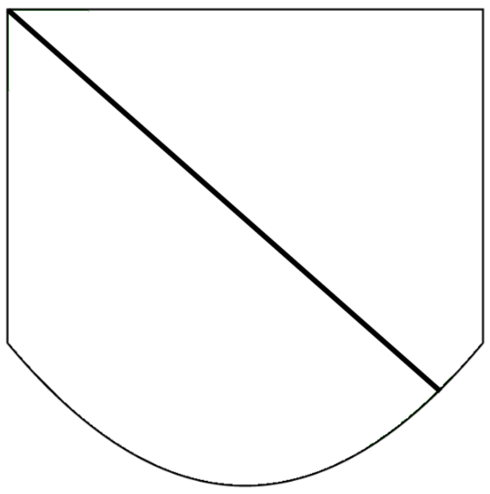
6.7.6 Saltire

The same as Cross but with Bend and Bend Sinister instead of Fess and Pall.

6.8 Implementing Charges

The graphical implementation of Charges mirrored the implementation of each individual partition's line of intersection, see figure 6.4 except instead of being a line a bar needed to be drawn instead.

Presenting an appropriately scaled charge for the size of the field presented some of a challenge. A thickness value for the charge was computed from the attributes of the field. The thinness for a charge was defined as the lesser of either the difference in the maximum Y value for the field and the minimum Y value for the field or the equivalent on the X axis divided by three.


(a) *"A Field partitioned Per Bend."*

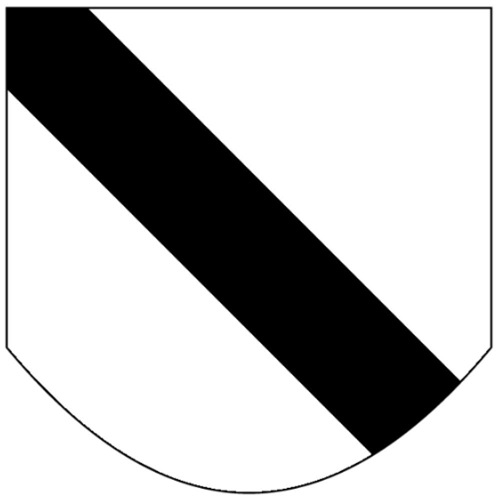

(b) *"A Field Charged Per Bend"*

Figure 6.4: The majority of the functionality for defining the line of partition for *Bend* and the Charge *Bend* is the same.

Only a little adapting was required to re-using the functionality from each Partitions definition to render a charge. Firstly the intersection points needed to be calculated as before then these points were included in a Canvas path that included also used the intersect points plus and minus the thickness value. This path was then passed to a Tinctures's Draw function and filled accordingly.

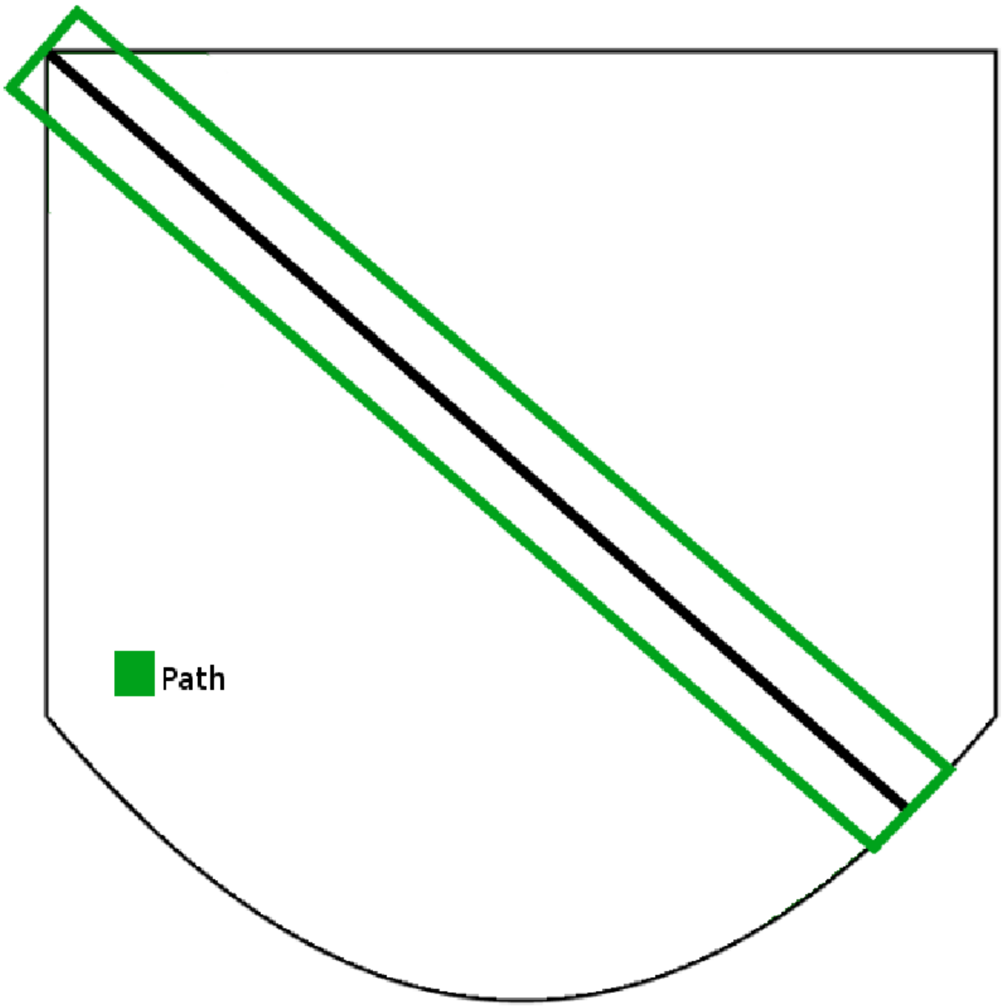


Figure 6.5: A visualisation of defining a path offset from where the equivalent partition would be by a thickness

6.9 A Third Party Library

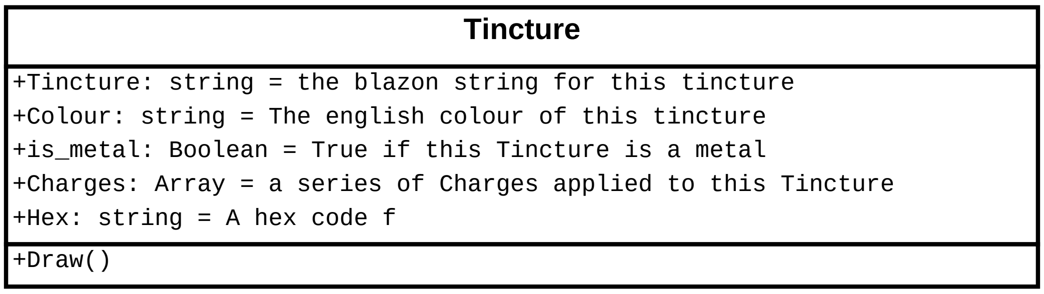
To calculate line intersections a third party library[11] written by *Kevin Lindsey* was utilised. The library features a whole suit of useful functions for performing two dimensional geometry. The reasoning behind using a library over implementing the behaviour internally were sane as there were time constrains on the application development and the library has been actively maintained since 2002 which suggest a high likeliness that it is properly implement and tested.

Chapter 7

Data Structures

For the sake of completeness a representation of the data structures used in the application will be given. This will help demonstrate how the objects can be used for both tokens and nodes in the parse tree as well as providing drawing functions and nesting other objects.

7.1 Tinctures



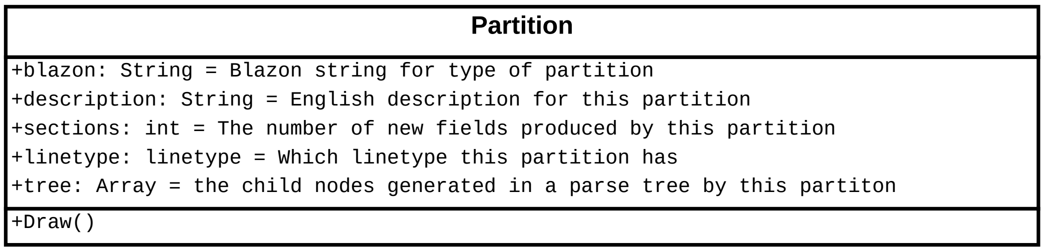
Tincture

```
+Tincture: string = the blazon string for this tincture
+Colour: string = The english colour of this tincture
+is_metal: Boolean = True if this Tincture is a metal
+Charges: Array = a series of Charges applied to this Tincture
+Hex: string = A hex code f
```

```
+Draw()
```

Figure 7.1: UML description of a Tincture.[1]

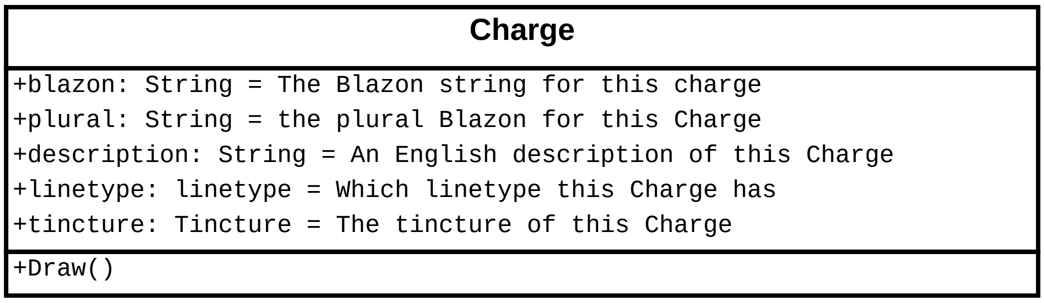
7.2 Partitions



```
Partition
+blazon: String = Blazon string for type of partition
+description: String = English description for this partition
+sections: int = The number of new fields produced by this partition
+linetype: linetype = Which linetype this partition has
+tree: Array = the child nodes generated in a parse tree by this partiton
+Draw()
```

Figure 7.2: UML description of a Partition[1]

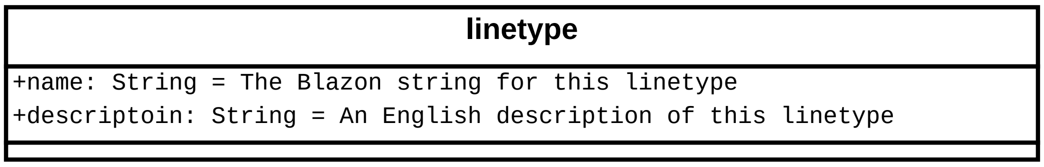
7.3 Charge



```
Charge
+blazon: String = The Blazon string for this charge
+plural: String = the plural Blazon for this Charge
+description: String = An English description of this Charge
+linetype: linetype = Which linetype this Charge has
+tincture: Tincture = The tincture of this Charge
+Draw()
```

Figure 7.3: UML description of a Charge.[1]

7.4 Linetype



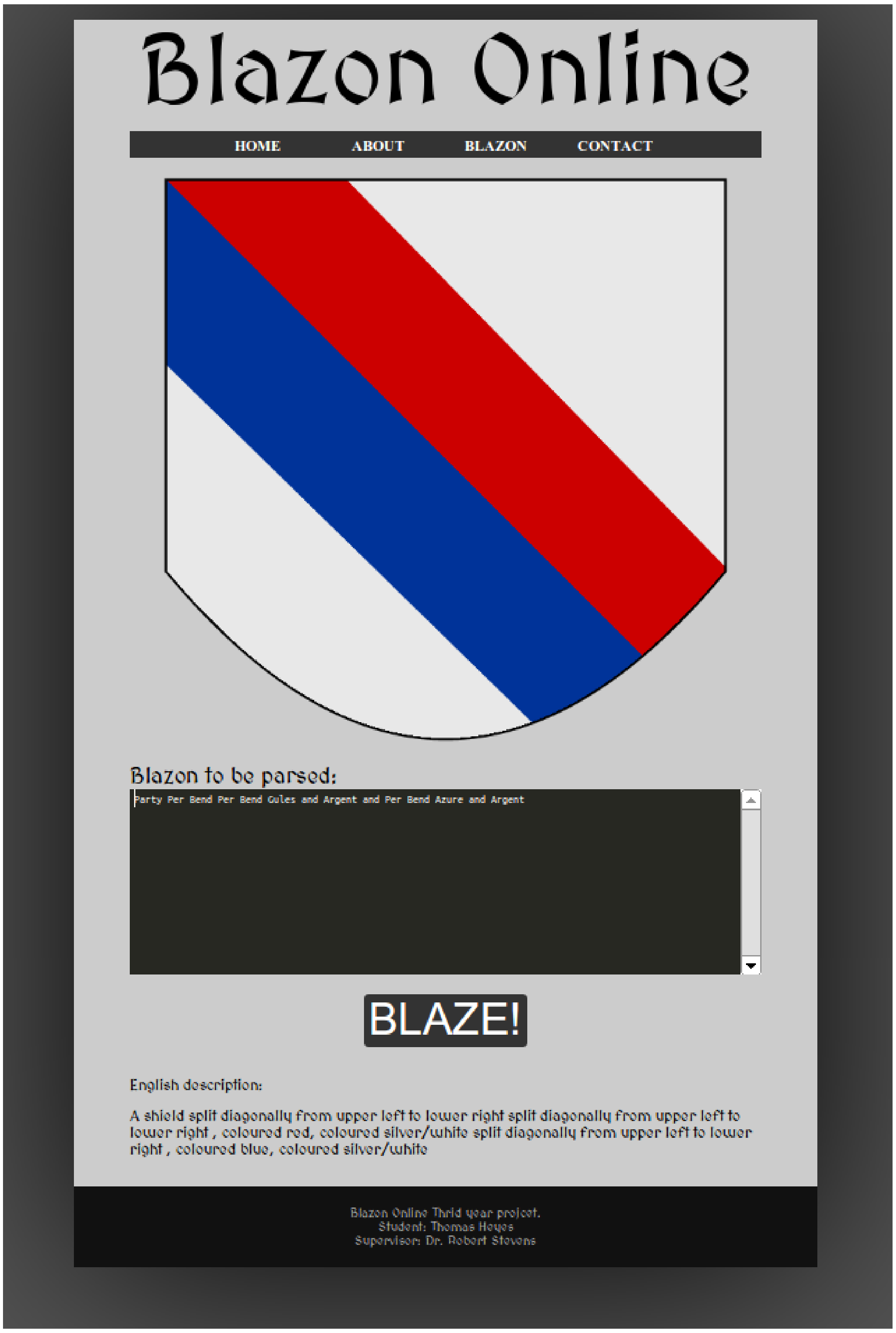
```
linetype
+name: String = The Blazon string for this linetype
+descriptoin: String = An English description of this linetype
```

Figure 7.4: Different line types valid in Blazon.[1]

Chapter 8

Design

As the application is a web application the design of the user interface was very important. The overall design implemented was designed to be straight forward to use and elegant in appearance as well as re-enforcing the overall theme of the application.



Blazon to be parsed:

```
Party Per Bend Per Bend Gules and Argent and Per Bend Azure and Argent
```

English description:

A shield split diagonally from upper left to lower right split diagonally from upper left to lower right , coloured red, coloured silver/white split diagonally from upper left to lower right , coloured blue, coloured silver/white

Blazon Online Thrid year project.
Student: Thomas Hayes
Supervisor: Dr. Robert Stevens

Figure 8.1: An overview of the user interface of the web application.

8.1 A Functional Layout

The main body off the application consists of three components, the *HTML5 Canvas* element onto which Shields are rendered, the text area

8.2 Maintaining the Blazon Theme

As Blazon was prominent from the twelfth century onwards the font used for the static text on the application encompasses a medieval style. Whilst only a minor detail it provides a complimenting style to the actual purpose and feel of the application.

8.3 Ace Editor

The input area is more than just a standard HTML Textarea, it is an instance of the *Ace Editor*[12]. The *Ace Editor* allows a text editor to be emended into a JavaScript application. The original idea was to implement syntax highlighting for Blazon using the editor however this was not due to constraints on development time.

Chapter 9

Development

The development of the application was performed using a test driven development model. There were some initial prototypes which encompassed a small subset of the Blazon language and gave a textual description only were developed also.

9.1 Background Research

The first couple of weeks of development time were spent exclusively on researching Blazon. The the Blazon language provides a great number features but is not particularly intuitive. Two texts in particular were used *Heraldry, Its Origins and Meaning*[7] and *The oxford guide to Heraldry*[8]. Both of the above provide a nice overview to heraldry with the former being very thorough on Blazon and the adoption of heraldry throughout Europe.

Obviously with *Luke Torjussen* having built a similar application[9] last year his system proved to be a very useful learning tool and later it was grate for testing.

Researching parsing techniques was also undertaken by consulting the *Dragon Book*[10]. This text is considered the industry standard on parsing and compilers and provided a wealth of information.

9.2 Prototypes

After researching the problem domain three small prototypes were developed. The first two were written in *Python* and the third was a *PHP* script.

Each prototype was built to pass a series of pre-defined tests defining the scope of functionality. This is how test driven development handles development life cycles, an iteration is treated as complete only when it passes all the tests set out for it.

The prototypes really helped incorporate the idea iterative life cycles when using a test driven development model. Each was a re-working of the iteration before and encompassed a slightly larger subset of the Blazon language then the last.

The first *Python* script incorporated the idea of Tinctures and and partitions, the second had a very naive implementation of geometric charges. The third prototype didn't increase the subset of the language being parsed but instead reflected an architectural change to the application as it was the first web based iteration.

9.3 Development of the Main Application

The decision was taken to make the Blazon parser a stand alone client side web application, relying on no significant infrastructure other than a web host. The reason behind this decision was to increase scalability and lower the workload of the server.

After the prototyping phase, another build of the application was produced in *JavaScript*, which is a web based client side scripting language supported by all major browsers. This build was then developed iteratively over the course of several months.

Again every iteration of the project increased the subset of Blazon that could be correctly parsed.

9.4 Graphical Representation

Once the parser was able to handle a large enough set of Blazon a graphical element was added to the project. The idea was to provide an accurate graphical representation of the Blazon sentence parsed by the application.

The *HTML5 Canvas* was chosen as the tool for rendering images as it has wide browser support and can be controlled using *JavaScript*. The rendering speed of the Canvas element is imperceivable to the human eye even for moderately complex drawings.

The development of the graphical side of the project was also iterative following a test driven model. The iterations mirrored those of the parsing implementation in that they started with a small subset of Blazon which was expanded on each subsequent iteration.

Chapter 10

Testing

Testing is one of the most important factors of application design allowing developments to be thoroughly checked and regulated before being fully integrated into the application. To test the code behind the Blazon parser two main types of testing were used, Black Box testing and Regression Testing.

10.1 Black Box Testing

Black Box Testing involves testing an application without being able to view the source code. Obviously this is tricky to achieve as I was both writing and testing the application. Pseudo Black Box testing can be achieved by writing test cases before implementing any functionality.

Black Box Testing is very simple in practice. Before even starting to write code for a new feature of the application a series of test cases describing the expected behaviour for that feature must be fully defined.

Next a series of test are defined according to the expected behaviour for example, *"The application must warn the user when not enough tinctures are declared in a Blazon sentence for the number of fields"*.

Initially this seems fairly simple to test, the feature would be tested by providing the application with a Blazon sentence to parse that didn't tincture all of the fields it declared to ensure that this case would occur and that when it did the warning was presented correctly.

It is also necessary to test the feature to ensure the warning is not shown inappropriately. When the Blazon sentence is valid so all the fields are tinctured the warning should not show so a valid Blazon sentence should be another test case for this feature.

Finally the warning should also not show if the sentence is invalid for another reason, so a series of invalid Blazon sentences which are incorrect but for a different reason should be provided to determine with a high degree of accuracy that the new feature does indeed work as intended.

After all the test cases have been determined, the feature is implemented. Once completed each of the defined test cases should be run in turn. If the feature achieves the intended behaviour as stated for a test case then the feature passes this test case. If the feature doesn't pass the intended behaviour for a test case then the feature hasn't been implemented correctly and needs to be altered so that it does pass this test case, altering the implementation of the feature means that all the test cases need to be ran again. This processes is repeated until the feature has been implemented in such a way that it passes all the desired test cases.

Black Box testing lends itself very well towards an agile like iterative development approach to an application. Progressively adding more functionality in small quick iterations and fully testing each one will allow quick progress and make debugging a relatively painless experience.

10.2 Regression Testing

Regression Testing involves checking the integrity of the rest of an applications code base once a new feature has been implemented.

Implementing a new feature tends to change the way old code worked. These changes are normally minor, an extra parameter in a function call or another method in an object to help it interface with the new feature. It is just as important to test these little changes as it is to test the new feature. *Small changes break things.* Regression testing involves testing parts of the application that were all ready implemented and ensuring that a minor change hasn't broken anything.

An example of Regression testing being useful during the development of this application was when I added a *"hex"* property to my tincture objects. Because I was writing my project in JavaScript I had to implement my own clone functions which simply created a new instance of a Tincture and set all its properties to that of the original. Sadly I had changed the constructor of Tincture to take a hex value but forgot to change the clone function to incorporate this change and if you call a constructor and don't provide enough parameters in JavaScript the method still gets called and the missing values as null. The result was my cloned Tinctures having a null hex value and therefore when it came to actually drawing the colour a null pointer error was thrown but the error was not in my new code.

Fortunately I noticed that the tincture being passed to my drawing functions had a null value for element and re-tested my cloning functions which now, were not producing the desired behaviour and therefore found my mistake.

Like Black Box testing, Regression Testing is very useful if not necessary for an application being developed in an agile manner. If used on a regular basis then it will defiantly help in the development of an application especially in regards to feature integration.

10.3 Blazon Seeking Missile

During the development of the project my flat mate *Johnny Houston* took it upon himself to write a python script lovingly named *"Blazon Seeking Missile"*. The sole aim of this script was to break my project by producing very very large blazon sentences as test data.

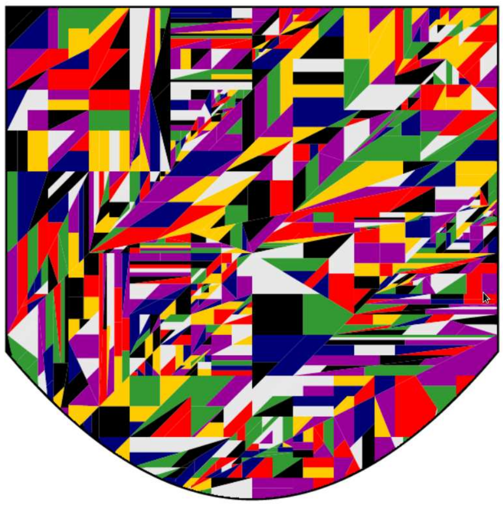


Figure 10.1: A rendering of a very complicated Blazon sentence

This was achieved by utilising the context free grammar defined in Chapter two. Starting with a single field the script takes an integer as a command line argument and proceeds to build a balanced tree of the arguments depth, representing a Blazon sentence, treating tinctured fields as leaves and partitions as nodes. The script randomly selects which partitions and tinctures to use.

This tool was very useful to me in testing my web application, even if it originally had more of a malicious intent. Essentially if my application can handle Blazon sentences containing $2\hat{1}1$ partitions then it will probably be able to handle more realistic input. It also proved the case that more complex designs are not always better by producing a lot of horrible colour schemes and designs.

10.4 Application Level Testing

It is also important to test the application as a whole as well as individual components. Does it properly parse Blazon into a rendered Image? How is it known that the application does indeed handle the subset of Blazon it is supposed to? What happens if part of the language that application is not able to handle is presented?

10.5 Testing for Completeness of the Blazon Subset

The subset of the language that the application can parse includes:

1. Tinctures
2. Partitions
3. Geometric Charges
4. Ordinaries
5. Semi Formal Charges

The completeness of the parsing can be tested by examining the data strictures outputted to the debug console in a browser. While the completeness of the drawing can be checked by simply looking at the result drawn on the HTML5 Canvas.

10.6 Bench Marking

Bibliography

[1] Mark E. Shoulson The pyBlazon wiki, https://code.google.com/p/pyblazon/wiki/PartyPer , Febuary 4th 2010

[2] Michel Pastoureau. Heraldry, Its Origins and Meaning. New Horizons. Published in 1996, translated in 1997.

[3] The language of Helaldry. http://www.obcgs.com/charge1.jpg

[4] Author: Sodacan, The Wikimedia Commons, Description: A Heraldic Lion in Rampant Attitude http://upload.wikimedia.org/wikipedia/commons/7/75/Lion_Rampant.svg 13 April 2009

[5] Author: Sodacan, The Wikimedia Commons, Description: A Heraldic Lion in Passant Attitude, http://upload.wikimedia.org/wikipedia/commons/f/f3/Lion_Passant.svg , 13 April 2009

[6] Adapted from: Phelan and Vanor , March 1 1989, http://khevron.tripod.com/armorial/awards.html

[7] Michel Pastoureau. Heraldry, Its Origins and Meaning. New Horizons. Published in 1996, translated in 1997.

[8] Thomas Woodcock and John Martin Robinson, The Oxford Guide to Heraldry, The Oxford University Press, Reissued in 2001

[9] Luke Torjussen, Translating Blason into Coats of Arms, May 2012

[10] Compilers principles, Techniques, & Tools, Alfred V. Aho, Monica S. Lam, Ravi Sethi, Jeffrey D. Ullman, Second edition, Published by Pearson, 2007

[11] Keven Lindsey, 2002, http://www.kevlindev.com/geometry/index.htm

[12] The ace editor home page, accessed 29th April 2013, http://ace.ajax.org/