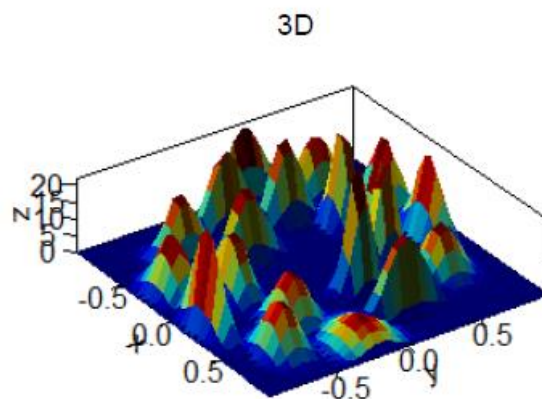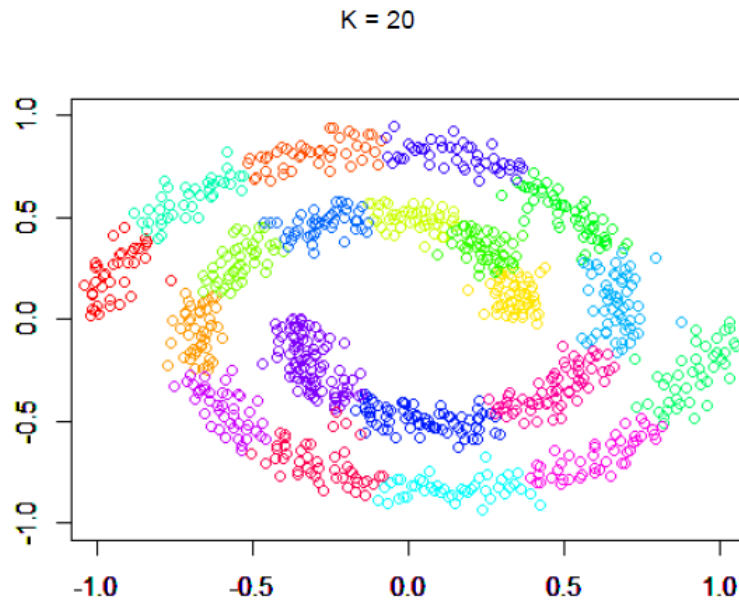# Reconhecimento de Padrões – Trabalho Final
Vinícius Claudino Ferraz

As aulas que mais me agradaram foram as de número 8 a 10, mistura de gaussianas.
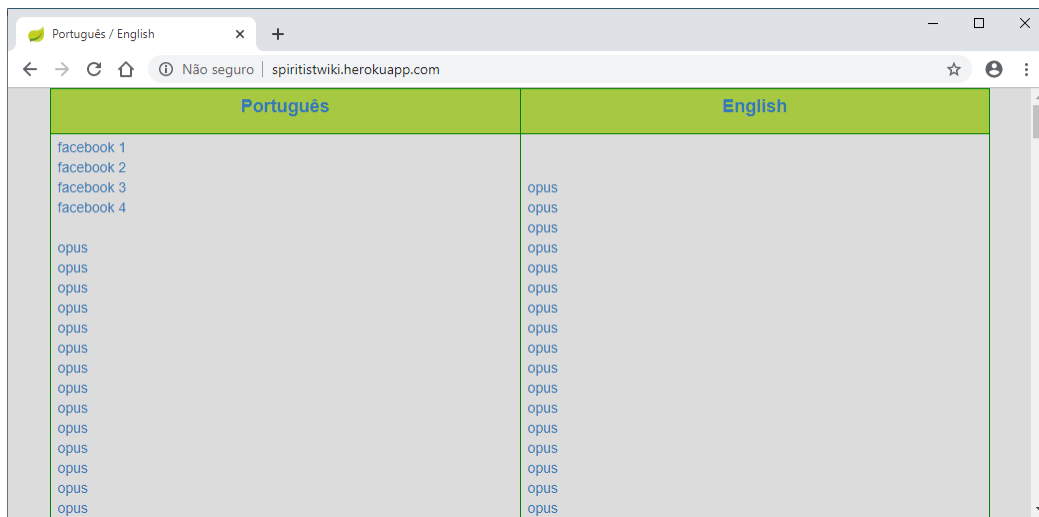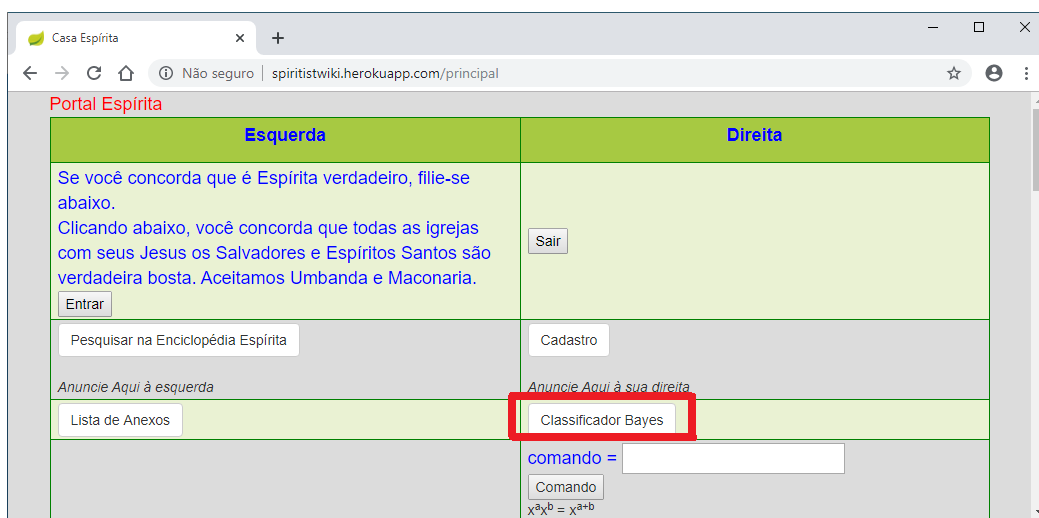
Relembrando:

K = 20

3D

Eu utilizei processamento de uma máquina do exterior em Java. A gente projeta, testa em localhost, faz git commit, e após configurar o projeto, ficou pronto o portal http://spiritistwiki.herokuapp.com/

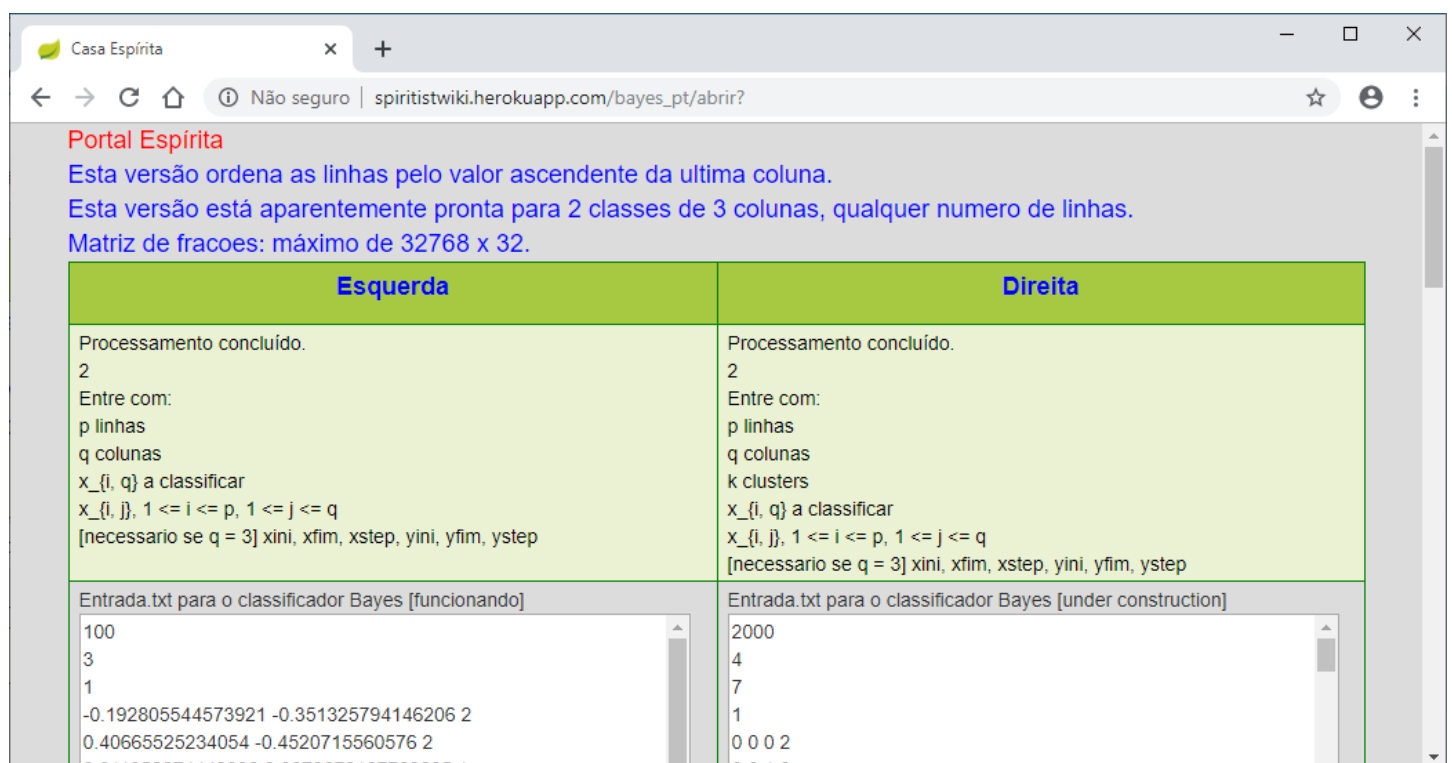Basicamente, passei tudo o que podia de R para Java.

Na raiz (root), o usuário clica em Português.

Na página principal, o usuário clica no botão Classificador Bayes.

Aparecem as informações abaixo, com duas textAreas (memorandos) para o usuário utilizar como entrada.

O sistema aceita qualquer número de linhas < 32768. (É incrivelmente lento. Depois de meia hora de processamento, o servidor derruba todos os processamentos. Como eu precisei de 24 horas de processamento, rodei em localhost, mesmo, em que não tem timeout.)

Aceita qualquer número de colunas < 32.

Opção com KMeans ou sem KMeans. Máximo de clusters = 32768.

O sistema não classifica nada além de 2 classes. Podem ser dois números fixos quaisquer. Se na última coluna houver mais de 2 valores, aborta. É necessário informar qual dos dois valores vai ser testado.

Em seguida pode-se separar as células da matriz por retorno de carro, ou uma única barra de espaço. O usuário informa matriz[0][0] ... matriz[0][q], depois matriz[1][0] ... matriz[1][q] ... matriz[p][q].

Para o caso de q = 3 (x, y, classe) eu coloquei opção de informar x de início, x de fim e stepx; y de início, y de fim e stepy, a fim de esquadrinhar o plano. Fazer uma previsão de -1 a 1 de 0.10 em 0.10 por exemplo.

Os números de entrada podem ser double (1.23e-23) ou frações (123/1234567890). A única parte que ficou lenta demais para usar frações é

```java
public static String pdfnvar(String[] x, String[] m, String det, String[][] inverse, int n) {
    String prod = produtoInterno(x, m, inverse, n);
    Double result = 1 / Math.sqrt(Math.pow((2 * Math.PI), n)) * 1 / Math.sqrt(SNum.FracToDouble(det))
            * Math.exp(-0.5 * SNum.FracToDouble(prod));

    if (result.isInfinite() || result.isNaN())
        result = 1.0;

    return SNum.DoubleToFrac(result);
}
```

(eu teria que usar expansão de Taylor para raiz quadrada e exponencial, ou método de Newton para achar pi, fixar erro = 1e-8 por exemplo...)

Veja como eu me recusei a fazer esta raiz quadrada.
Se o número tiver dois milhões de dígitos, eu faço pesquisa binária em uma string de um milhão de dígitos. A raiz de uma fração é a raiz do numerador sobre a raiz do denominador. Muito impróprio.

```java
public static String sqrt(String n, String x) {
    String i, min, max;
    SFrac qr = new SFrac();
    String Result;

    if (x.charAt(0) == '-')
        return "0";

    min = "";
    max = "";
    Integer L = x.length();
    qr = Divide(L.toString(), n);
    i = Subtrai("1", qr.d);
    if (i.charAt(0) == '-')
        i = "0";
    while (SNumCompare(i, qr.n) <= 0) {
        max = max + "9";
        min = min + "0";
        i = Soma(i, "1");
    }
    min = Util.delete(min, 1, 1);
    min = Util.char2String((char) 1) + min;
    min = min.replace(Util.char2String((char) 1), "1");

    do {
        qr = Divide(Soma(min, max), "2");
        Result = qr.n;
        qr.d = Potencia(Result, n);
        if (qr.d.equals(x))
            return Result;
        if (SNumCompare(qr.d, x) < 0)
            min = Soma(Result, "1");
        else
            max = Subtrai(Result, "1");

    } while (SNumCompare(min, max) <= 0);

    Result = max;
    return Result;
}
```

Bom, então é isso. Talvez seja o primeiro programa a fazer isso sem instalar nada, nem mesmo copiar um EXE. Online.
Talvez seja o mais lento deles e o pior feito no ano de 2019.
Deixe-me introduzir o que é Java.

```java
@RequestMapping("/bayes_pt/abrir")
public String bayesPT(HttpSession session, final Map<String, Object> modelMap) {
    modelMap.put("message", "Esta vers&#xe3;o ordena as linhas pelo valor ascendente da ultima coluna.\n"
        + "Esta vers&#xe3;o est&#xe1; aparentemente pronta para 2 classes de 3 colunas, qualquer numero de linhas.\n"
        + "Matriz de fracoes: m&#xe1;ximo de " + MyTask.MAXYV + " x " + MyTask.MAXXV + ".\n");
    session.setAttribute("concluido", "Processamento conclu&#xed;do.");
    session.setAttribute("saida1",
        "Entre com:<br/>p linhas<br/>q colunas<br/>x_{i, q} a classificar<br/>x_{i, j}, 1 <= i <= p, 1 <= j <= q<br/>[n");
    session.setAttribute("saida2",
        "Entre com:<br/>p linhas<br/>q colunas<br/>k clusters<br/>x_{i, q} a classificar<br/>x_{i, j}, 1 <= i <= p, 1 <");
    return "bayes_pt";
}
```

O usuário requisita a página /bayes_pt
O servidor devolve a ele mensagens e atributos de sessão.
Elas ficam lá no servidor uma sessão por usuário até detectar que o usuário se foi.
(Sessão expira. Necessário fazer login novamente.)

Quando o usuário clica no botão PREVER,

```java
@PostMapping("/bayes_pt/selecionar1")
public String bayesPTSelecionar1(HttpSession session, String valor1, Map<String, Object> modelMap)
        throws SQLException {
    myThread(session, valor1, 1);
    modelMap.put("message", "Tarefa tipo 1 iniciada com sucesso.");
    modelMap.put("valor1", valor1);
    return "bayes_pt";
}

private void myThread(HttpSession session, String valor1, Integer numeroBotao) {
    MyTask task = new MyTask(session, valor1, numeroBotao);
    ExecutorService executorService = Executors.newCachedThreadPool();
    executorService.execute(task);
    executorService.shutdown();
    session.setAttribute("concluido", "Rodando");
}
```

Inicia uma tarefa que vai demorar mais de 30 segundos. Como você pode ver, dessa vez é um POST de muitas informações do memorando, ao contrário dos GETS até agora. A tarefa é iniciada. A página abre para o usuário. O processamento continua em background.
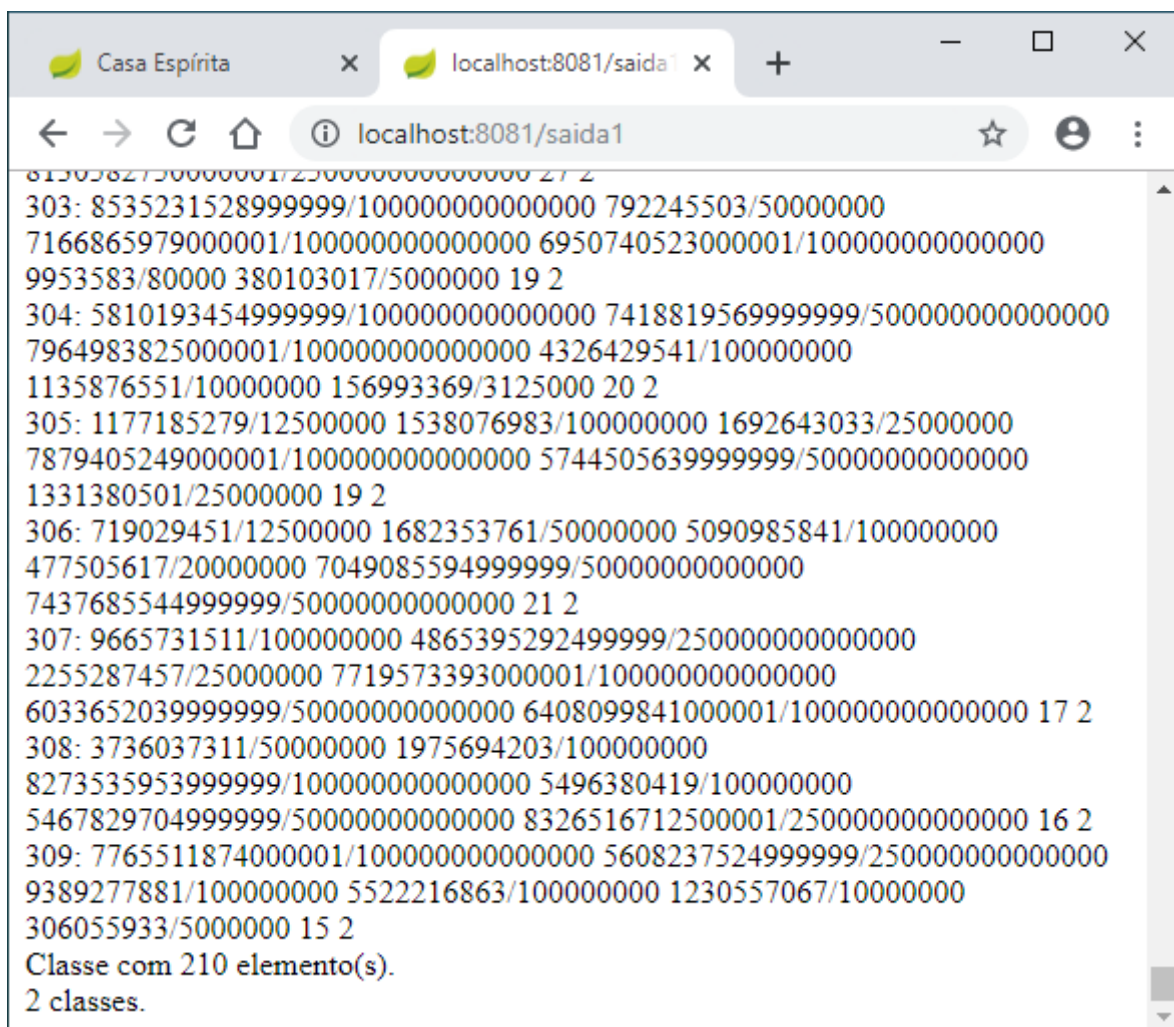
```javascript
function startWorker() {
    if (typeof (Worker) !== "undefined") {
        if (typeof (w) == "undefined") {
            w = new Worker("/js/my_worker.js");
        }
        w.onmessage = function(event) {
            document.getElementById("result1").innerHTML = event.data;
            document.getElementById("result2").innerHTML = event.data;
            $.ajax({
                type : 'GET',
                url : "/saida1",
                dataType : "html",
                success : function(data) {
                    $("#saida1").html(data);
                }
            });
            $.ajax({
                type : 'GET',
                url : "/saida2",
                dataType : "html",
                success : function(data) {
                    $("#saida2").html(data);
                }
            });
            if (document.getElementById("concluido1").innerHTML == "Processamento concluído.")
                stopWorker();
        };
    }
}

$(document).ready(function() {
    startWorker();
});
</script>
```

Isso é javaScript e ajax. Um worker conta segundos 1, 2, 3... Toda vez que passar um segundo, ele atualiza na tela os endereços /saida1 e /saida2.
Se você digitar isso no browser, vai ver em separado assim:

81305827300000017230000000000000 27 2
303: 853523152899999/10000000000000 792245503/50000000
7166865979000001/10000000000000 6950740523000001/100000000000000
9953583/80000 380103017/5000000 19 2
304: 5810193454999999/100000000000000 7418819569999999/500000000000000
7964983825000001/100000000000000 4326429541/100000000
1135876551/10000000 156993369/3125000 20 2
305: 1177185279/12500000 1538076983/100000000 1692643033/25000000
7879405249000001/100000000000000 5744505639999999/50000000000000
1331380501/25000000 19 2
306: 719029451/12500000 1682353761/50000000 5090985841/100000000
477505617/20000000 7049085594999999/50000000000000
7437685544999999/50000000000000 21 2
307: 9665731511/100000000 4865395292499999/250000000000000
2255287457/25000000 7719573393000001/100000000000000
6033652039999999/50000000000000 6408099841000001/100000000000000 17 2
308: 3736037311/50000000 1975694203/100000000
8273535953999999/100000000000000 5496380419/100000000
5467829704999999/50000000000000 8326516712500001/250000000000000 16 2
309: 7765511874000001/100000000000000 5608237524999999/250000000000000
9389277881/100000000 5522216863/100000000 1230557067/10000000
306055933/5000000 15 2
Classe com 210 elemento(s).
2 classes.

Toda vez que eu altero minha variável privada, eu torno-a pública assim:

```java
public void setSaida1(String saida1) {
    this.saida1 = saida1;
    session.setAttribute("saida1", saida1.replace("\n", "<br/>"));
}

public String getSaida2() {
    return saida2;
}

public void setSaida2(String saida2) {
    this.saida2 = saida2;
    session.setAttribute("saida2", saida2.replace("\n", "<br/>"));
}
```

Agora vamos ao que importa.

```
Read pN; // máximo de linhas
Read qN; // máx de colunas
Read kN; // # clusters
Read target; // ou 1 ou 2
Read matriz[i][j];// pN * qN
Ordenar() pela coluna q – 1;
q++;
coluna[q-2] = kmeans();
do {
    novoCentro = ...;
} while (novoCentro != centro);
```

```java
public static String[][] ordenar(String[][] entrada, Integer p, Integer q) {
    String[][] matriz = new String[p][q];
    for (int i = 0; i < p; i++)
        for (int j = 0; j < q; j++)
            matriz[i][j] = entrada[i][j];

    String s;
    // bubble
    for (int i = 0; i < p - 1; i++)
        for (int j = i + 1; j < p; j++)
            if (SNum.FracCompare(matriz[i][q - 1], matriz[j][q - 1]) > 0)
                for (int k = 0; k < q; k++) {
                    s = matriz[i][k];
                    matriz[i][k] = matriz[j][k];
                    matriz[j][k] = s;
                }

    return matriz;
}
```
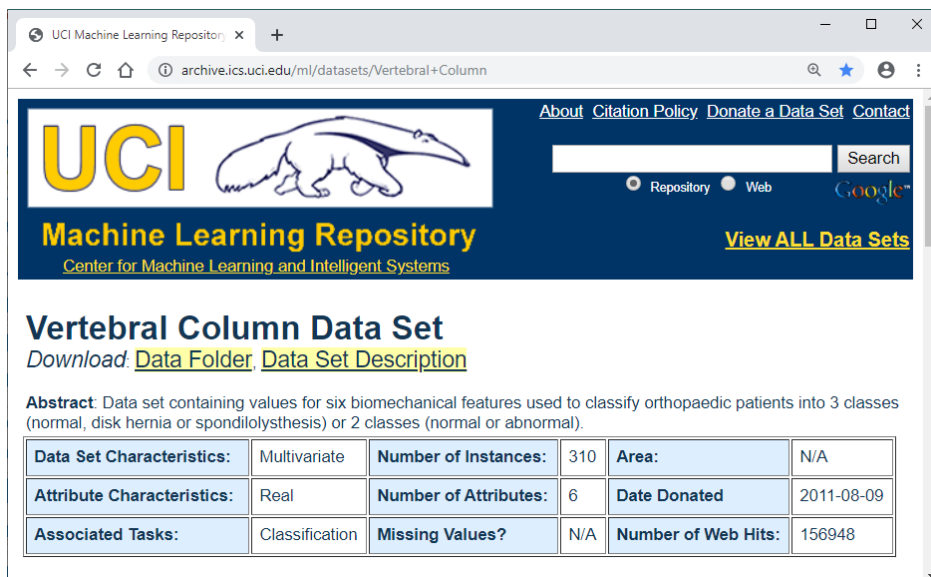
Acima método bolha, mesmo.

Qual foi o problema que escolhi?

Passei problemas para inverter a covariância 20 x 20 do clima tempo.
Troquei por um genérico menorzinho abaixo.

Queremos saber se a coluna vertebral é normal ou anormal.
309 linhas (310 – 1)
7 colunas
30 clusters (primeiro eu quebrei a cara com 10)
1 previsão da última linha
alvo = 2 (primeiro eu quebrei a cara com 1, a maldição do tamanho dos dados.)

```
@relation column_2C_weka

@attribute pelvic_incidence numeric
@attribute pelvic_tilt numeric
@attribute lumbar_lordosis_angle numeric
@attribute sacral_slope numeric
@attribute pelvic_radius numeric
@attribute degree_spondylolisthesis numeric

@attribute class {Abnormal, Normal}

@data
63.0278175,22.55258597,39.60911701,40.47523153,98.67291675,-0.254399986,Abnormal
39.05695098,10.06099147,25.01537822,28.99595951,114.4054254,4.564258645,Abnormal
68.83202098,22.21848205,50.09219357,46.61353893,105.9851355,-3.530317314,Abnormal
69.29700807,24.65287791,44.31123813,44.64413017,101.8684951,11.21152344,Abnormal
49.71285934,9.652074879,28.317406,40.06078446,108.1687249,7.918500615,Abnormal
54.60031622,21.48897426,29.36021618,33.11134196,118.3433212,-1.471067262,Normal
34.38229939,2.062682882,32.39081996,32.31961651,128.3001991,-3.365515555,Normal
45.07545026,12.30695118,44.58317718,32.76849908,147.8946372,-8.941709421,Normal
47.90356517,13.61668819,36,34.28687698,117.4490622,-4.245395422,Normal
53.93674778,20.72149628,29.22053381,33.21525149,114.365845,-0.421010392,Normal
61.44659663,22.6949683,46.17034732,38.75162833,125.6707246,-2.707879517,Normal
45.25279209,8.693157364,41.5831264,36.55963472,118.5458418,0.214750167,Normal
33.84164075,5.073991409,36.64123294,28.76764934,123.9452436,-0.199249089,Normal
```

Encontrou o centro do kmeans() em 11 iterações.
if (não forem 2 classes) return;
targetClass = primeira ou segunda (boolean);
for (int dez = 0; dez < 10; dez++) {...} // aquele velho esquema de dividir em 10%
teste [i][j] = 10% linhas;
trein [i][j] = 90% linhas;
xc2 [i][j] = 1 – targetClass;
m1 [j] = média 1;
m2 [j] = média 2;
cov1 = Bayes.cov(trein, treinN, qN - 2, m1);
cov2 = Bayes.cov(xc2, xcN[1 - targetClass], qN - 2, m2);

Como calcular matriz de covariância em java?

```java
public static String[][] cov(String[][] A, Integer linhas, Integer colunas, String[] avg) {
    String[][] result = new String[colunas][colunas];
    String n = linhas.toString();
    Integer i, j, k;

    // a matriz eh simetrica
    for (j = 0; j < colunas; j++)
        for (k = j; k < colunas; k++)
            result[j][k] = "0";

    for (j = 0; j < colunas; j++)
        for (k = j; k < colunas; k++) {
            System.out.println("j = " + j.toString() + ", k = " + k.toString());
            for (i = 0; i < linhas; i++)
                result[j][k] = SNum.FracAdd(result[j][k],
                        SNum.FracMul(SNum.FracSub(A[i][j], avg[j]), SNum.FracSub(A[i][k], avg[k])));
        }

    for (i = 0; i < colunas; i++)
        for (j = i; j < colunas; j++) {
            result[i][j] = SNum.FracDiv(result[i][j], n);
            // Double d = SNum.FracToDouble(result[i][j]);
            // System.out.println("eee " + d.toString());
        }

    for (i = 0; i < colunas; i++)
        for (j = i + 1; j < colunas; j++)
            result[j][i] = result[i][j];

    return result;
}
```

Determinante abaixo (ordem de n!). Já pensou aguardar 20! milissegundos?

```java
public static String det(String[][] K, Integer n) {
    if (n.equals(2))
        return SNum.FracSub(SNum.FracMul(K[0][0], K[1][1]), SNum.FracMul(K[1][0], K[0][1]));

    String result = "0", sinal = "1";
    for (Integer j = 0; j < n; j++) {
        if (!K[0][j].equals("0")) {
            System.out.println("n = " + n.toString() + ", j = " + j.toString());
            result = SNum.FracAdd(result, SNum.FracMul(sinal, SNum.FracMul(K[0][j], det(cofator(K, j, n), n - 1))));
        }
        sinal = SNum.SNumOposto(sinal);
    }

    return result;
}
```

Método do cofator:

```java
// retorna A sem a linha 1 e sem a coluna
public static String[][] cofator(String[][] A, int coluna, int n) {
    String[][] result = new String[n - 1][n - 1];

    for (int i = 0; i < n - 1; i++)
        for (Integer j = 0, k = 0; j < n - 1; j++, k++) {
            if (k.equals(coluna))
                k++;
            result[i][j] = A[i + 1][k];
        }

    return result;
}
```

Como calcular a inversa?

```java
public static String[][] inversa(String[][] entrada,
        String d, Integer n) throws Exception {
    String result[][] = new String[n][n];
    for (int j = 0; j < n; j++) {
        // pivotear Entrada (x) = (e_j) ==> result[j] = x
        String[] x = solve(entrada, j, n);
        for (int i = 0; i < n; i++)
            result[i][j] = x[i];
    }
    return result;
}
```

Se Ax = b = (01000), então x = A^{-1} b = coluna da inversa. Pivotear. Caso no meio do pivoteamento achar uma coluna de zeros, considere que a matriz é singular.

```java
public static String[] solve(String[][] entrada, int k, int n) throws Exception {
    String[][] A = new String[n][n];
    String[] b = new String[n];
    Integer i, j;
    for (i = 0; i < n; i++)
        for (j = 0; j < n; j++)
            A[i][j] = entrada[i][j];
    for (i = 0; i < n; i++)
        b[i] = kronecker(i, k);
    // Ax = b
    for (int pivoti = 0; pivoti < n; pivoti++) {
        Integer pivotj = pivoti;
        while (A[pivoti][pivotj].equals("0") && (pivoti < n))
            pivoti++;
        if (pivoti >= n)
            throw new Exception("Matriz singular.");
        if (!pivotj.equals(pivoti)) {
            // xchg b[pivoti], b[pivotj]
            String s = b[pivoti];
            b[pivoti] = b[pivotj];
            b[pivotj] = s;
            for (j = 0; j < n; j++) {
                // xchg A[pivoti][*], A[pivotj][*]
                s = A[pivoti][j];
                A[pivoti][j] = A[pivotj][j];
                A[pivotj][j] = s;
            }
            pivoti = pivotj;
        }
        ~~~
    }
    // Diagonal x = b'
    for (i = 0; i < n; i++) {
        b[i] = SNum.FracDiv(b[i], A[i][i]);
    }
    return b;
}
```

Finalmente, classifique as linhas de teste.

```java
for (i = 0; i < testeN; i++) {
    System.out.println("i = " + i.toString() + " pdfnvar");
    pp[i][0] = SNum.FracMul(Bayes.pdfnvar(teste[i], m1, det1, inverse1, qN - 2), treinN.toString());
    pp[i][1] = SNum.FracMul(Bayes.pdfnvar(teste[i], m2, det2, inverse2, qN - 2),
            xcN[1 - targetClass].toString());
    System.out.println("Ponto A");
    Double d1 = SNum.FracToDouble(pp[i][0]);
    System.out.println("Ponto B");
    Double d2 = SNum.FracToDouble(pp[i][1]);
    if (Bayes.loggy)
        System.out.println("p0 = " + d1.toString() + " p1 = " + d2.toString());
    setSaida2(saida2 + "p" + i.toString() + "0 = " + d1.toString() + "\n" + "p" + i.toString() + "1 = "
            + d2.toString() + "\n");
}
```

Se o cluster é da classe alvo, setFlag diferente de zero (aproveita para contar):

```java
Integer[] flag = new Integer[kN];
for (j = 0; j < kN; j++)
    flag[j] = 0;
for (i = 0; i < pN; i++) {
    if (matriz[i][qN - 1].equals(sEquiv[0]) && (targetClass.equals(0))) {
        j = Integer.parseInt(matriz[i][qN - 2]);
        flag[j]++;
    } else if (matriz[i][qN - 1].equals(sEquiv[1]) && (targetClass.equals(1))) {
        j = Integer.parseInt(matriz[i][qN - 2]);
        flag[j]++;
    }
}
```

Depois de 24 horas de processamento, conseguimos dez acurácias:

```
Integer acertos = 0;
for (i = 0; i < testeN; i++) {
    String numerador = "0", denom = "0";
    for (j = 0; j < kN; j++)
        if (flag[j] > 0)
            numerador = SNum.FracAdd(numerador, pp[i][0]);
        else
            denom = SNum.FracAdd(denom, pp[i][1]);
    if (!denom.equals("0")) {
        String f = SNum.FracDiv(numerador, denom);
        if (SNum.FracCompare(f, "1") >= 0)
            acertos++; // M = targetClass + 1;
    } else
        System.out.println(i.toString() + " denom = 0");
    // nao incrementar acertos significa M != targetClass + 1
}

acuracia[dez] = SNum.FracDiv(SNum.FracMul(acertos.toString(), "100"), testeN.toString());
```

Dentre as dez, escolha max.
Repita teste[], trein [], xc2[], m1[], m2[];
cov1, cov2, det1, det2, inverse1, inverse2;
pp[testeN][0], pp[testeN][1], flag;

Já podemos fazer previsões!

read # linhas;
read teste[i][j];
A previsão diz se é 2 ou 1.
return "Processamento concluído.";

Acabo de pensar: nada é maior que 100%. Vou colocar aqui um atalho para quando acertos = todos().

O código está privado em http://github.com/boralaemcasa/spiritistwiki.git

Exercício 1: modo gráfico em java.
Return bmp png jpg ao invés de html.
Eu sei gerar bitmap em Delphi com PontoXY(cos(pi), sin(pi), clblue);
Em java, não estou preparado.

Exercício 2: Futura implementação: 3, 4, 5... C classes.

Exercício 3: Como aumentar a velocidade do processamento?

Temos algumas conclusões sobre colunas vertebrais.

Abaixo a saída completa.

Principio do processamento 2 = k_means.

Procurando centros
Lida a linha 99
Lida a linha 199
Lida a linha 299
Iteracao 1
linha 99
linha 199
linha 299

Iteracao 2
linha 99
linha 199
linha 299
Iteracao 3
linha 99
linha 199
linha 299
Iteracao 4
linha 99
linha 199
linha 299
Iteracao 5
linha 99
linha 199
linha 299
Iteracao 6
linha 99
linha 199
linha 299
Iteracao 7
linha 99
linha 199
linha 299
Iteracao 8
linha 99
linha 199
linha 299
Iteracao 9
linha 99
linha 199
linha 299
Iteracao 10
linha 99
linha 199
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296: 4544374959/100000000 4953035899/500000000 4499999999/100000000 3553767779/100000000 326142081/2000000 507882883/25000000 28 2
297: 2989263263/50000000 446983083/25000000 5920646143/100000000 5238242742499999/125000000000000 5965955544999999/50000000000000 1106193437/50000000 27 2
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304: 5810193454999999/100000000000000 7418819569999999/500000000000000
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305: 1177185279/12500000 1538076983/100000000 1692643033/25000000 7879405249000001/100000000000000
5744505639999999/50000000000000 1331380501/25000000 19 2
306: 719029451/12500000 1682353761/50000000 5090985841/100000000 477505617/20000000
7049085594999999/50000000000000 7437685544999999/50000000000000 21 2
307: 9665731511/100000000 4865395292499999/250000000000000 2255287457/25000000
7719573393000001/100000000000000 6033652039999999/50000000000000 6408099841000001/100000000000000
17 2
308: 3736037311/50000000 1975694203/100000000 8273535953999999/100000000000000 5496380419/100000000
5467829704999999/50000000000000 8326516712500001/250000000000000 16 2
309: 7765511874000001/100000000000000 5608237524999999/250000000000000 9389277881/100000000
5522216863/100000000 1230557067/10000000 306055933/5000000 15 2
Classe com 210 elemento(s).
2 classes.

acurácia[0] = 100% // eu vi isso crescer com o número de clusters. Testei com a espiral, por exemplo.
acurácia[1] = 100%
acurácia[2] = 100%
acurácia[3] = 100%
acurácia[4] = 100%
acurácia[5] = 100%
acurácia[6] = 100%
acurácia[7] = 100%
acurácia[8] = 100%
acurácia[9] = 100%

2 // Se numerador/denominador = treinamento/(classe oposta) > 1, então M = 1, senão M = 2.
Processamento concluído.

Conclusão: a previsão é boa. O java é bom.
Há interface y otras cositas más a melhorar.
Todo o conteúdo desta disciplina é Javeável.