Федеральное государственное бюджетное образовательное
учреждение высшего образования
«Сибирский государственный университет
телекоммуникаций и информатики» (СибГУТИ)

Кафедра ПМиК

Лабораторная работа 4
по дисциплине «Прикладная стеганография»

Выполнил: ст. гр.
ЗМП-41 Лёвкин И. А.

Проверила: Мерзлякова Е.Ю.

Новосибирск 2025

Описание методов стегоанализа

RS-анализ

Авторы: Jessica Fridrich, Miroslav Goljan, Rui Du.

RS-анализ – это статистический метод, разработанный для обнаружения стеганографических изменений в изображениях, особенно при использовании LSB-стеганографии (замены наименее значимых битов). Метод основан на анализе корреляционных свойств групп пикселей после применения определённых функций дискретизации.

Основные этапы метода:

1. Изображение разделяется на непересекающиеся блоки пикселей.
2. Для каждого блока вычисляются две характеристики: регулярность (R) и сингулярность (S), которые показывают, насколько изменяются статистические свойства изображения после внедрения скрытых данных.
3. Анализ соотношения R и S позволяет определить факт наличия стеговложения и оценить его объем.

Преимущества:

- Эффективен против LSB-стеганографии.
- Позволяет оценить длину скрытого сообщения.

Недостатки:

- Чувствителен к шумам и сжатию изображения.
- Менее эффективен против адаптивных методов стеганографии.

Asymptotically Uniformly Most Powerful (AUMP)

Авторы: Andrew D. Ker, Patrick Bas, Tomáš Pevný.

AUMP представляет собой статистический подход, основанный на теории оптимальных решающих правил. Он предназначен для обнаружения стеганографических изменений в условиях малых размеров встраиваемых сообщений и асимптотически стремится к равномерно наиболее мощному критерию.

Основные принципы:

- Использует логарифмические отношения правдоподобия (log-likelihood ratio) для проверки гипотез.
- Оптимизирован для работы в условиях, когда размер встроенного сообщения стремится к нулю (асимптотический анализ).
- Позволяет строить детекторы, близкие к оптимальным по критерию Неймана-Пирсона.

Преимущества:

- Высокая эффективность при малых объемах скрытых данных.
- Универсальность – может применяться к различным стеганографическим методам.

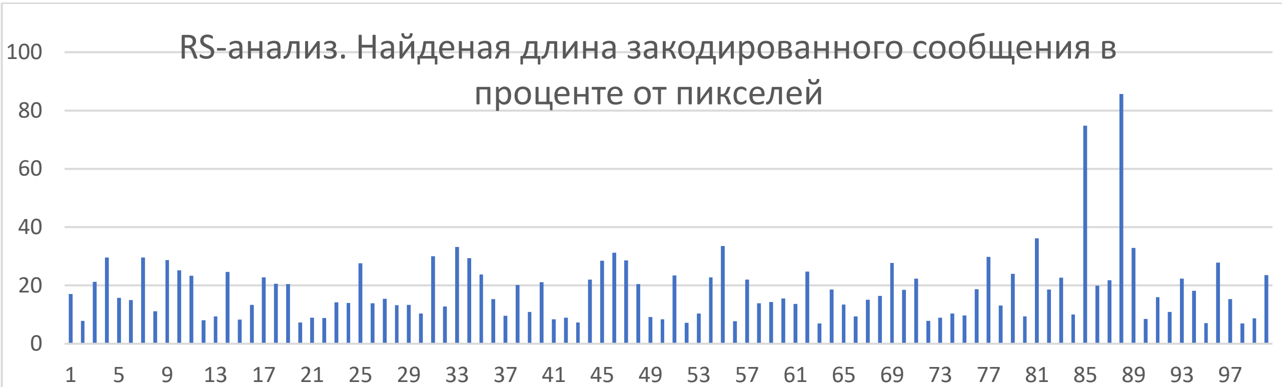
Недостатки:

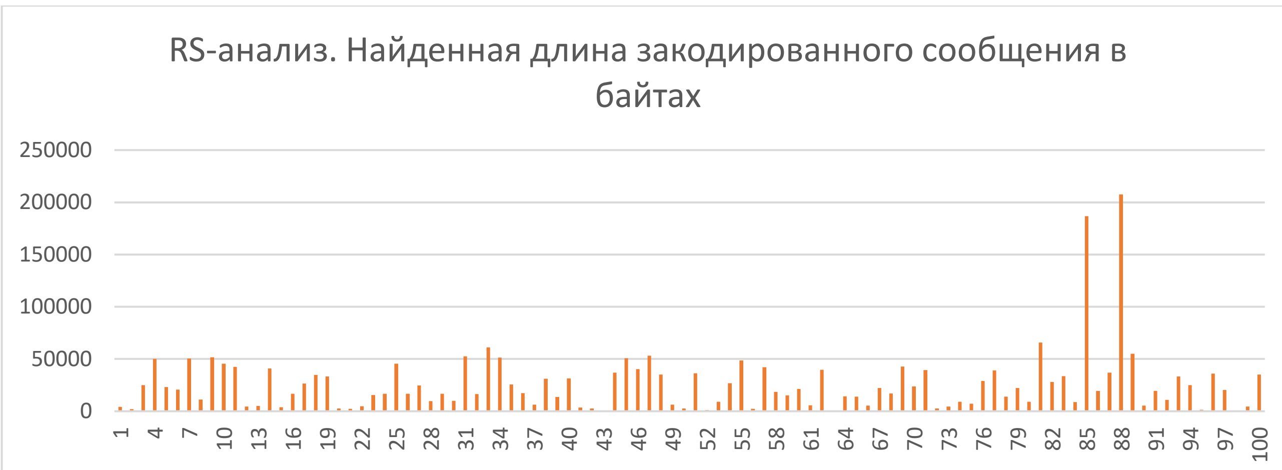
- Требует точного знания статистики покрытия.
- Вычислительно сложен по сравнению с эвристическими методами.

Применение и сравнение методов

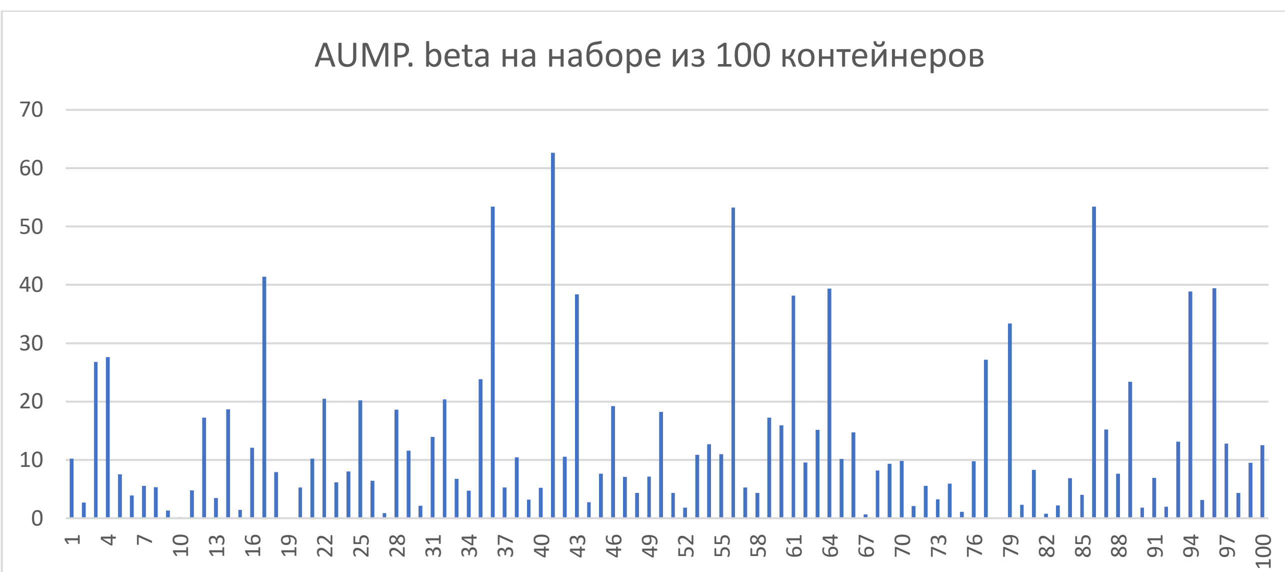
Проведём анализ 100 контейнеров, содержащих сообщение с помощью RS-анализа и AUMP.

RS-анализ





AUMP



Вывод по 100 контейнерам RS-анализа

```
encoded_1.bmp
Average result: 17,10%
Estimated message length (in bytes): 4170.273016291594

encoded_2.bmp
Average result: 7,86%
Estimated message length (in bytes): 1974.772590345115

encoded_3.bmp
Average result: 21,20%
Estimated message length (in bytes): 24860.66238791518

encoded_4.bmp
Average result: 29,55%
Estimated message length (in bytes): 50226.40580636884

encoded_5.bmp
Average result: 15,80%
Estimated message length (in bytes): 22996.678889774324

encoded_6.bmp
Average result: 15,02%
Estimated message length (in bytes): 20808.796929071163

encoded_7.bmp
Average result: 29,53%
Estimated message length (in bytes): 50538.04696213917
```

```
encoded_8.bmp
Average result: 11,09%
Estimated message length (in bytes): 11213.31532871331

encoded_9.bmp
Average result: 28,73%
Estimated message length (in bytes): 51569.84555729444

encoded_10.bmp
Average result: 25,17%
Estimated message length (in bytes): 45575.239308337004

encoded_11.bmp
Average result: 23,28%
Estimated message length (in bytes): 42403.27237603203

encoded_12.bmp
Average result: 8,10%
Estimated message length (in bytes): 4504.087246972909

encoded_13.bmp
Average result: 9,38%
Estimated message length (in bytes): 5067.2640087058435

encoded_14.bmp
Average result: 24,66%
Estimated message length (in bytes): 41005.23056174029

encoded_15.bmp
```

```
Average result: 8,34%
Estimated message length (in bytes): 3902.738193876855


encoded_16.bmp
Average result: 13,33%
Estimated message length (in bytes): 16700.729014049644


encoded_17.bmp
Average result: 22,73%
Estimated message length (in bytes): 26363.481055382326


encoded_18.bmp
Average result: 20,61%
Estimated message length (in bytes): 34905.83621521642


encoded_19.bmp
Average result: 20,48%
Estimated message length (in bytes): 33248.39171667113


encoded_20.bmp
Average result: 7,25%
Estimated message length (in bytes): 2561.046186060542


encoded_21.bmp
Average result: 8,89%
Estimated message length (in bytes): 2347.4503107509636


encoded_22.bmp
Average result: 8,82%
```

```
Estimated message length (in bytes): 4699.350699273489


encoded_23.bmp

Average result: 14,18%

Estimated message length (in bytes): 15427.346720963706


encoded_24.bmp

Average result: 14,00%

Estimated message length (in bytes): 16599.2690795609


encoded_25.bmp

Average result: 27,59%

Estimated message length (in bytes): 45417.97240695092


encoded_26.bmp

Average result: 13,86%

Estimated message length (in bytes): 16756.34156159868


encoded_27.bmp

Average result: 15,39%

Estimated message length (in bytes): 24820.53223669811


encoded_28.bmp

Average result: 13,23%

Estimated message length (in bytes): 9664.354505714604


encoded_29.bmp

Average result: 13,33%

Estimated message length (in bytes): 16607.358449594656
```

```
encoded_30.bmp
Average result: 10,42%
Estimated message length (in bytes): 9890.427054243315

encoded_31.bmp
Average result: 29,97%
Estimated message length (in bytes): 52442.73435770984

encoded_32.bmp
Average result: 12,76%
Estimated message length (in bytes): 16410.486811986142

encoded_33.bmp
Average result: 33,16%
Estimated message length (in bytes): 61128.88954528181

encoded_34.bmp
Average result: 29,33%
Estimated message length (in bytes): 51230.745898087815

encoded_35.bmp
Average result: 23,74%
Estimated message length (in bytes): 25445.70059421772

encoded_36.bmp
Average result: 15,34%
Estimated message length (in bytes): 17265.275577312947
```

```
encoded_37.bmp
Average result: 9,61%
Estimated message length (in bytes): 6151.444026175092

encoded_38.bmp
Average result: 20,08%
Estimated message length (in bytes): 31096.619441503677

encoded_39.bmp
Average result: 10,88%
Estimated message length (in bytes): 13736.117187588308

encoded_40.bmp
Average result: 21,12%
Estimated message length (in bytes): 31446.843425287385

encoded_41.bmp
Average result: 8,40%
Estimated message length (in bytes): 3651.0394331898815

encoded_42.bmp
Average result: 8,91%
Estimated message length (in bytes): 2606.4372293540655

encoded_43.bmp
Average result: 7,28%
Estimated message length (in bytes): 180.2697890595747

encoded_44.bmp
```

```
Average result: 22,01%
Estimated message length (in bytes): 36888.17650655243

encoded_45.bmp
Average result: 28,45%
Estimated message length (in bytes): 50825.809341200664

encoded_46.bmp
Average result: 31,27%
Estimated message length (in bytes): 40179.06577607384

encoded_47.bmp
Average result: 28,58%
Estimated message length (in bytes): 53118.7353757788

encoded_48.bmp
Average result: 20,44%
Estimated message length (in bytes): 35041.78183181133

encoded_49.bmp
Average result: 9,16%
Estimated message length (in bytes): 6281.097031722593

encoded_50.bmp
Average result: 8,44%
Estimated message length (in bytes): 2755.154862094578

encoded_51.bmp
Average result: 23,46%
```

```
Estimated message length (in bytes): 36387.42443436161


encoded_52.bmp

Average result: 7,17%

Estimated message length (in bytes): 1078.8943621928788


encoded_53.bmp

Average result: 10,35%

Estimated message length (in bytes): 9055.327855647838


encoded_54.bmp

Average result: 22,75%

Estimated message length (in bytes): 26754.337323100932


encoded_55.bmp

Average result: 33,48%

Estimated message length (in bytes): 48536.34874337083


encoded_56.bmp

Average result: 7,75%

Estimated message length (in bytes): 2265.689195109833


encoded_57.bmp

Average result: 22,00%

Estimated message length (in bytes): 42148.00796449851


encoded_58.bmp

Average result: 13,83%

Estimated message length (in bytes): 18646.329008353816
```

```
encoded_59.bmp
Average result: 14,37%
Estimated message length (in bytes): 15268.892182599748

encoded_60.bmp
Average result: 15,48%
Estimated message length (in bytes): 21261.12478000147

encoded_61.bmp
Average result: 13,70%
Estimated message length (in bytes): 5639.339566607324

encoded_62.bmp
Average result: 24,75%
Estimated message length (in bytes): 39549.14870681628

encoded_63.bmp
Average result: 6,98%
Estimated message length (in bytes): 64.8088558742161

encoded_64.bmp
Average result: 18,56%
Estimated message length (in bytes): 14185.098222342811

encoded_65.bmp
Average result: 13,48%
Estimated message length (in bytes): 14084.598333717156
```

```
encoded_66.bmp

Average result: 9,42%

Estimated message length (in bytes): 5421.939116570213


encoded_67.bmp

Average result: 15,07%

Estimated message length (in bytes): 22227.299159157505


encoded_68.bmp

Average result: 16,46%

Estimated message length (in bytes): 17079.081851900835


encoded_69.bmp

Average result: 27,70%

Estimated message length (in bytes): 42869.18737938494


encoded_70.bmp

Average result: 18,47%

Estimated message length (in bytes): 23742.24955201026


encoded_71.bmp

Average result: 22,31%

Estimated message length (in bytes): 39257.756941611704


encoded_72.bmp

Average result: 7,89%

Estimated message length (in bytes): 2512.8926890685166


encoded_73.bmp
```

```
Average result: 8,93%
Estimated message length (in bytes): 4422.844847929353


encoded_74.bmp
Average result: 10,33%
Estimated message length (in bytes): 9077.482292954226


encoded_75.bmp
Average result: 9,76%
Estimated message length (in bytes): 7324.7882572891285


encoded_76.bmp
Average result: 18,72%
Estimated message length (in bytes): 29105.475162284278


encoded_77.bmp
Average result: 29,79%
Estimated message length (in bytes): 39021.95311170787


encoded_78.bmp
Average result: 13,07%
Estimated message length (in bytes): 14042.48832526811


encoded_79.bmp
Average result: 23,96%
Estimated message length (in bytes): 22237.98180542556


encoded_80.bmp
Average result: 9,37%
```

```
Estimated message length (in bytes): 9059.625739587824


encoded_81.bmp

Average result: 36,17%

Estimated message length (in bytes): 65661.69909259168


encoded_82.bmp

Average result: 18,64%

Estimated message length (in bytes): 28031.17137695938


encoded_83.bmp

Average result: 22,68%

Estimated message length (in bytes): 33701.28540859873


encoded_84.bmp

Average result: 10,05%

Estimated message length (in bytes): 8654.866592379032


encoded_85.bmp

Average result: 74,85%

Estimated message length (in bytes): 186775.57500296942


encoded_86.bmp

Average result: 19,91%

Estimated message length (in bytes): 19583.934420855083


encoded_87.bmp

Average result: 21,83%

Estimated message length (in bytes): 37022.269866513794
```

```
encoded_88.bmp
Average result: 85,67%
Estimated message length (in bytes): 207687.54217960953

encoded_89.bmp
Average result: 32,92%
Estimated message length (in bytes): 54940.3993477918

encoded_90.bmp
Average result: 8,45%
Estimated message length (in bytes): 5392.801772424719

encoded_91.bmp
Average result: 15,98%
Estimated message length (in bytes): 19400.461739605846

encoded_92.bmp
Average result: 10,89%
Estimated message length (in bytes): 10961.346873112434

encoded_93.bmp
Average result: 22,32%
Estimated message length (in bytes): 33149.63639265663

encoded_94.bmp
Average result: 18,15%
Estimated message length (in bytes): 24992.66685020252
```

```
encoded_95.bmp

Average result: 7,10%

Estimated message length (in bytes): 1397.4036971321532


encoded_96.bmp

Average result: 27,86%

Estimated message length (in bytes): 35970.46119530605


encoded_97.bmp

Average result: 15,30%

Estimated message length (in bytes): 20380.19592027833


encoded_98.bmp

Average result: 6,93%

Estimated message length (in bytes): 72.64080223103042


encoded_99.bmp

Average result: 8,68%

Estimated message length (in bytes): 4567.524357734648


encoded_100.bmp

Average result: 23,59%

Estimated message length (in bytes): 35233.13221801197
```

Вывод по 100 контейнерам AUMP:

```
encoded_1.bmp
Detection statistic beta = 110.2235

encoded_2.bmp
```

```
Detection statistic beta = -2.6770

encoded_3.bmp
Detection statistic beta = 26.7905

encoded_4.bmp
Detection statistic beta = 27.6240

encoded_5.bmp
Detection statistic beta = 7.5426

encoded_6.bmp
Detection statistic beta = -3.8916

encoded_7.bmp
Detection statistic beta = 5.5650

encoded_8.bmp
Detection statistic beta = -5.3294

encoded_9.bmp
Detection statistic beta = -1.3443

encoded_10.bmp
Detection statistic beta = -0.1709

encoded_11.bmp
Detection statistic beta = -4.7991

encoded_12.bmp
Detection statistic beta = -17.2238

encoded_13.bmp
Detection statistic beta = 3.4400

encoded_14.bmp
Detection statistic beta = 18.6907

encoded_15.bmp
Detection statistic beta = 1.4507

encoded_16.bmp
Detection statistic beta = 12.0550

encoded_17.bmp
Detection statistic beta = 41.3982

encoded_18.bmp
```

```
Detection statistic beta = -7.9041

encoded_19.bmp
Detection statistic beta = -0.0482

encoded_20.bmp
Detection statistic beta = 5.2907

encoded_21.bmp
Detection statistic beta = -10.1980

encoded_22.bmp
Detection statistic beta = 20.4634

encoded_23.bmp
Detection statistic beta = 6.1717

encoded_24.bmp
Detection statistic beta = -7.9993

encoded_25.bmp
Detection statistic beta = 20.1940

encoded_26.bmp
Detection statistic beta = 6.4004

encoded_27.bmp
Detection statistic beta = -0.8708

encoded_28.bmp
Detection statistic beta = -18.5942

encoded_29.bmp
Detection statistic beta = -11.5904

encoded_30.bmp
Detection statistic beta = 2.1358

encoded_31.bmp
Detection statistic beta = -13.9523

encoded_32.bmp
Detection statistic beta = 20.3787

encoded_33.bmp
Detection statistic beta = 6.7397

encoded_34.bmp
```

```
Detection statistic beta = 4.7456

encoded_35.bmp
Detection statistic beta = 23.8133

encoded_36.bmp
Detection statistic beta = 53.4237

encoded_37.bmp
Detection statistic beta = 5.2651

encoded_38.bmp
Detection statistic beta = 10.4190

encoded_39.bmp
Detection statistic beta = -3.1706

encoded_40.bmp
Detection statistic beta = 5.2002

encoded_41.bmp
Detection statistic beta = -62.6189

encoded_42.bmp
Detection statistic beta = 10.5314

encoded_43.bmp
Detection statistic beta = 38.3673

encoded_44.bmp
Detection statistic beta = 2.7506

encoded_45.bmp
Detection statistic beta = 7.6166

encoded_46.bmp
Detection statistic beta = 19.2081

encoded_47.bmp
Detection statistic beta = 7.0668

encoded_48.bmp
Detection statistic beta = 4.3595

encoded_49.bmp
Detection statistic beta = -7.1470

encoded_50.bmp
```

```
Detection statistic beta = 18.2007

encoded_51.bmp
Detection statistic beta = 4.3320

encoded_52.bmp
Detection statistic beta = 1.8192

encoded_53.bmp
Detection statistic beta = -10.8473

encoded_54.bmp
Detection statistic beta = 12.6650

encoded_55.bmp
Detection statistic beta = 10.9950

encoded_56.bmp
Detection statistic beta = 53.2497

encoded_57.bmp
Detection statistic beta = 5.2756

encoded_58.bmp
Detection statistic beta = -4.3203

encoded_59.bmp
Detection statistic beta = -17.2596

encoded_60.bmp
Detection statistic beta = -15.8968

encoded_61.bmp
Detection statistic beta = 38.1420

encoded_62.bmp
Detection statistic beta = -9.5560

encoded_63.bmp
Detection statistic beta = 15.1761

encoded_64.bmp
Detection statistic beta = 39.3854

encoded_65.bmp
Detection statistic beta = 10.1599

encoded_66.bmp
```

```
Detection statistic beta = -14.7212

encoded_67.bmp
Detection statistic beta = 0.6536

encoded_68.bmp
Detection statistic beta = 8.1877

encoded_69.bmp
Detection statistic beta = -9.3077

encoded_70.bmp
Detection statistic beta = 9.8347

encoded_71.bmp
Detection statistic beta = 2.1080

encoded_72.bmp
Detection statistic beta = 5.5581

encoded_73.bmp
Detection statistic beta = -3.2463

encoded_74.bmp
Detection statistic beta = 5.9448

encoded_75.bmp
Detection statistic beta = 1.0917

encoded_76.bmp
Detection statistic beta = 9.7758

encoded_77.bmp
Detection statistic beta = 27.1936

encoded_78.bmp
Detection statistic beta = -0.0346

encoded_79.bmp
Detection statistic beta = 33.3936

encoded_80.bmp
Detection statistic beta = -2.3158

encoded_81.bmp
Detection statistic beta = -8.2851

encoded_82.bmp
```

```
Detection statistic beta = -0.7741

encoded_83.bmp
Detection statistic beta = 2.2132

encoded_84.bmp
Detection statistic beta = 6.8512

encoded_85.bmp
Detection statistic beta = 3.9996

encoded_86.bmp
Detection statistic beta = 53.4238

encoded_87.bmp
Detection statistic beta = -15.2261

encoded_88.bmp
Detection statistic beta = -7.6045

encoded_89.bmp
Detection statistic beta = -23.3877

encoded_90.bmp
Detection statistic beta = 1.7931

encoded_91.bmp
Detection statistic beta = -6.9119

encoded_92.bmp
Detection statistic beta = 1.9626

encoded_93.bmp
Detection statistic beta = 13.1152

encoded_94.bmp
Detection statistic beta = -38.8914

encoded_95.bmp
Detection statistic beta = 3.1523

encoded_96.bmp
Detection statistic beta = 39.4272

encoded_97.bmp
Detection statistic beta = 12.7835

encoded_98.bmp
```

```
Detection statistic beta = 4.3463

encoded_99.bmp
Detection statistic beta = 9.4742

encoded_100.bmp
Detection statistic beta = 12.4950
```

Листинг

RS-анализ

RSAnalysis.java

```
/*
 *    Digital Invisible Ink Toolkit
 *    Copyright (C) 2005  K. Hempstalk
 *
 *    This program is free software; you can redistribute it and/or
modify
 *    it under the terms of the GNU General Public License as published
by
 *    the Free Software Foundation; either version 2 of the License, or
 *    (at your option) any later version.
 *
 *    This program is distributed in the hope that it will be useful,
 *    but WITHOUT ANY WARRANTY; without even the implied warranty of
 *    MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
 *    GNU General Public License for more details.
 *
 *    You should have received a copy of the GNU General Public License
 *    along with this program; if not, write to the Free Software
 *    Foundation, Inc., 675 Mass Ave, Cambridge, MA 02139, USA.
 *
 *         @author Kathryn Hempstalk
 */

import java.awt.image.BufferedImage;
import java.io.File;
import java.util.Collections;
import java.util.Enumeration;
import java.util.List;
import java.util.Vector;
import javax.imageio.ImageIO;

/**
 * RS analysis for a stego-image.
 * <P>
 * RS analysis is a system for detecting LSB steganography proposed by
Dr.
 * Fridrich at Binghamton University, NY. You can visit her webpage for
more
```

```
 * information - {@link http://www.ws.binghamton.edu/fridrich/} <BR>
 * Implemented as described in "Reliable detection of LSB steganography
in color
 * and grayscale images" by J. Fridrich, M. Goljan and R. Du.
 * <BR>
 * This code was produced with the aid of the authors and has been
verified as a
 * correct implementation of RS Analysis. Their assistance has proved
 * invaluable.
 *
 * @author Kathryn Hempstalk
 */
public class RSAnalysis extends PixelBenchmark {

    //CONSTRUCTORS
    /**
     * Creates a new RS analysis with a given mask size of m x n.
     *
     * Each alternating bit is set to 1. Eg for a mask of size 2x2 the
resulting
     * mask will be {1,0;0,1}. Two masks are used - one is the inverse of
the
     * other.
     *
     * @param m The x mask size.
     * @param n The y mask size.
     */
    public RSAnalysis(int m, int n) {
        //two masks
        mMask = new int[2][m * n];

        //iterate through them and set alternating bits
        int k = 0;
        for (int i = 0; i < n; i++) {
            for (int j = 0; j < m; j++) {
                if (((j % 2) == 0 && (i % 2) == 0)
                        || ((j % 2) == 1 && (i % 2) == 1)) {
                    mMask[0][k] = 1;
                    mMask[1][k] = 0;
                } else {
                    mMask[0][k] = 0;
                    mMask[1][k] = 1;
                }
                k++;
```

```
            }
        }

        //set up the mask size.
        mM = m;
        mN = n;
    }

    //FUNCTIONS
    /**
     * Does an RS analysis of a given image.
     * <P>
     * The analysis data returned is specified by name in the
getResultNames()
     * method.
     *
     * @param image The image to analyse.
     * @param colour The colour to analyse.
     * @param overlap Whether the blocks should overlap or not.
     * @return The analysis information.
     */
    public double[] doAnalysis(BufferedImage image, int colour, boolean
overlap) {

        //get the images sizes
        int imgx = image.getWidth(), imgy = image.getHeight();

        int startx = 0, starty = 0;
        int block[] = new int[mM * mN];
        double numregular = 0, numsingular = 0;
        double numnegreg = 0, numnegsing = 0;
        double numunusable = 0, numnegunusable = 0;
        double variationB, variationP, variationN;

        while (startx < imgx && starty < imgy) {
            //this is done once for each mask...
            for (int m = 0; m < 2; m++) {
                //get the block of data
                int k = 0;
                for (int i = 0; i < mN; i++) {
                    for (int j = 0; j < mM; j++) {
                        block[k] = image.getRGB(startx + j, starty + i);
                        k++;
                    }
```

```
            }

            //get the variation the block
            variationB = getVariation(block, colour);

            //now flip according to the mask
            block = flipBlock(block, mMask[m]);
            variationP = getVariation(block, colour);
            //flip it back
            block = flipBlock(block, mMask[m]);

            //negative mask
            mMask[m] = this.invertMask(mMask[m]);
            variationN = getNegativeVariation(block, colour,
mMask[m]);
            mMask[m] = this.invertMask(mMask[m]);

            //now we need to work out which group each belongs to
            //positive groupings
            if (variationP > variationB) {
                numregular++;
            }
            if (variationP < variationB) {
                numsingular++;
            }
            if (variationP == variationB) {
                numunusable++;
            }

            //negative mask groupings
            if (variationN > variationB) {
                numnegreg++;
            }
            if (variationN < variationB) {
                numnegsing++;
            }
            if (variationN == variationB) {
                numnegunusable++;
            }

            //now we keep going...
        }
        //get the next position
        if (overlap) {
```

```
                startx += 1;
            } else {
                startx += mM;
            }

            if (startx >= (imgx - 1)) {
                startx = 0;
                if (overlap) {
                    starty += 1;
                } else {
                    starty += mN;
                }
            }
            if (starty >= (imgy - 1)) {
                break;
            }
        }

        //get all the details needed to derive x...
        double totalgroups = numregular + numsingular + numunusable;
        double allpixels[] = this.getAllPixelFlips(image, colour, 
overlap);
        double x = getX(numregular, numnegreg, allpixels[0], 
allpixels[2],
                numsingular, numnegsing, allpixels[1], allpixels[3]);

        //calculate the estimated percent of flipped pixels and message 
length
        double epf, ml;
        if (2 * (x - 1) == 0) {
            epf = 0;
        } else {
            epf = Math.abs(x / (2 * (x - 1)));
        }

        if (x - 0.5 == 0) {
            ml = 0;
        } else {
            ml = Math.abs(x / (x - 0.5));
        }

        //now we have the number of regular and singular groups...
        double results[] = new double[28];
```

```
        //save them all...
        //these results
        results[0] = numregular;
        results[1] = numsingular;
        results[2] = numnegreg;
        results[3] = numnegsing;
        results[4] = Math.abs(numregular - numnegreg);
        results[5] = Math.abs(numsingular - numnegsing);
        results[6] = (numregular / totalgroups) * 100;
        results[7] = (numsingular / totalgroups) * 100;
        results[8] = (numnegreg / totalgroups) * 100;
        results[9] = (numnegsing / totalgroups) * 100;
        results[10] = (results[4] / totalgroups) * 100;
        results[11] = (results[5] / totalgroups) * 100;

        //all pixel results
        results[12] = allpixels[0];
        results[13] = allpixels[1];
        results[14] = allpixels[2];
        results[15] = allpixels[3];
        results[16] = Math.abs(allpixels[0] - allpixels[1]);
        results[17] = Math.abs(allpixels[2] - allpixels[3]);
        results[18] = (allpixels[0] / totalgroups) * 100;
        results[19] = (allpixels[1] / totalgroups) * 100;
        results[20] = (allpixels[2] / totalgroups) * 100;
        results[21] = (allpixels[3] / totalgroups) * 100;
        results[22] = (results[16] / totalgroups) * 100;
        results[23] = (results[17] / totalgroups) * 100;

        //overall results
        results[24] = totalgroups;
        results[25] = epf;
        results[26] = ml;
        results[27] = ((imgx * imgy * 3) * ml) / 8;

        return results;
    }

    /**
     * Gets the x value for the p=x(x/2) RS equation. See the paper for
more
     * details.
     *
     * @param r The value of Rm(p/2).
```

```
     * @param rm The value of R-m(p/2).
     * @param r1 The value of Rm(1-p/2).
     * @param rm1 The value of R-m(1-p/2).
     * @param s The value of Sm(p/2).
     * @param sm The value of S-m(p/2).
     * @param s1 The value of Sm(1-p/2).
     * @param sm1 The value of S-m(1-p/2).
     * @return The value of x.
     */
    private double getX(double r, double rm, double r1, double rm1,
            double s, double sm, double s1, double sm1) {

        double x = 0; //the cross point.

        double dzero = r - s; // d0 = Rm(p/2) - Sm(p/2)
        double dminuszero = rm - sm; // d-0 = R-m(p/2) - S-m(p/2)
        double done = r1 - s1; // d1 = Rm(1-p/2) - Sm(1-p/2)
        double dminusone = rm1 - sm1; // d-1 = R-m(1-p/2) - S-m(1-p/2)

        //get x as the root of the equation
        //2(d1 + d0)x^2 + (d-0 - d-1 - d1 - 3d0)x + d0 - d-0 = 0
        //x = (-b +or- sqrt(b^2-4ac))/2a
        //where ax^2 + bx + c = 0 and this is the form of the equation
        //thanks to a good friend in Dunedin, NZ for helping with maths
        //and to Miroslav Goljan's fantastic Matlab code
        double a = 2 * (done + dzero);
        double b = dminuszero - dminusone - done - (3 * dzero);
        double c = dzero - dminuszero;

        if (a == 0) //take it as a straight line
        {
            x = c / b;
        }

        //take it as a curve
        double discriminant = Math.pow(b, 2) - (4 * a * c);

        if (discriminant >= 0) {
            double rootpos = ((-1 * b) + Math.sqrt(discriminant)) / (2 *
a);
            double rootneg = ((-1 * b) - Math.sqrt(discriminant)) / (2 *
a);
```

```
            //return the root with the smallest absolute value (as per
paper)
            if (Math.abs(rootpos) <= Math.abs(rootneg)) {
                x = rootpos;
            } else {
                x = rootneg;
            }
        } else {
            //maybe it's not the curve we think (straight line)
            double cr = (rm - r) / (r1 - r + rm - rm1);
            double cs = (sm - s) / (s1 - s + sm - sm1);
            x = (cr + cs) / 2;
        }

        if (x == 0) {
            double ar = ((rm1 - r1 + r - rm) + (rm - r) / x) / (x - 1);
            double as = ((sm1 - s1 + s - sm) + (sm - s) / x) / (x - 1);
            if (as > 0 | ar < 0) {
                //let's assume straight lines again...
                double cr = (rm - r) / (r1 - r + rm - rm1);
                double cs = (sm - s) / (s1 - s + sm - sm1);
                x = (cr + cs) / 2;
            }
        }
        return x;
    }

    /**
     * Gets the RS analysis results for flipping performed on all pixels.
     *
     * @param image The image to analyse.
     * @param colour The colour to analyse.
     * @param overlap Whether the blocks should overlap.
     * @return The analysis information for all flipped pixels.
     */
    private double[] getAllPixelFlips(BufferedImage image, int colour,
boolean overlap) {

        //setup the mask for everything...
        int[] allmask = new int[mM * mN];
        for (int i = 0; i < allmask.length; i++) {
            allmask[i] = 1;
        }
```

```
        //now do the same as the doAnalysis() method
        //get the images sizes
        int imgx = image.getWidth(), imgy = image.getHeight();

        int startx = 0, starty = 0;
        int block[] = new int[mM * mN];
        double numregular = 0, numsingular = 0;
        double numnegreg = 0, numnegsing = 0;
        double numunusable = 0, numnegunusable = 0;
        double variationB, variationP, variationN;

        while (startx < imgx && starty < imgy) {
            //done once for each mask
            for (int m = 0; m < 2; m++) {
                //get the block of data
                int k = 0;
                for (int i = 0; i < mN; i++) {
                    for (int j = 0; j < mM; j++) {
                        block[k] = image.getRGB(startx + j, starty + i);
                        k++;
                    }
                }

                //flip all the pixels in the block (NOTE: THIS IS WHAT'S
DIFFERENT
                //TO THE OTHER doAnalysis() METHOD)
                block = flipBlock(block, allmask);

                //get the variation the block
                variationB = getVariation(block, colour);

                //now flip according to the mask
                block = flipBlock(block, mMask[m]);
                variationP = getVariation(block, colour);
                //flip it back
                block = flipBlock(block, mMask[m]);

                //negative mask
                mMask[m] = this.invertMask(mMask[m]);
                variationN = getNegativeVariation(block, colour,
mMask[m]);
                mMask[m] = this.invertMask(mMask[m]);

                //now we need to work out which group each belongs to
```

```
        }

            //positive groupings
            if (variationP > variationB) {
                numregular++;
            }
            if (variationP < variationB) {
                numsingular++;
            }
            if (variationP == variationB) {
                numunusable++;
            }

            //negative mask groupings
            if (variationN > variationB) {
                numnegreg++;
            }
            if (variationN < variationB) {
                numnegsing++;
            }
            if (variationN == variationB) {
                numnegunusable++;
            }

            //now we keep going...
        }
        //get the next position
        if (overlap) {
            startx += 1;
        } else {
            startx += mM;
        }

        if (startx >= (imgx - 1)) {
            startx = 0;
            if (overlap) {
                starty += 1;
            } else {
                starty += mN;
            }
        }
        if (starty >= (imgy - 1)) {
            break;
        }
    }
```

```
        //save all the results (same order as before)
        double results[] = new double[4];

        results[0] = numregular;
        results[1] = numsingular;
        results[2] = numnegreg;
        results[3] = numnegsing;

        return results;
    }

    /**
     * Returns an enumeration of all the result names.
     *
     * @return The names of all the results.
     */
    public Enumeration getResultNames() {
        Vector names = new Vector(28);
        names.add("Number of regular groups (positive)");
        names.add("Number of singular groups (positive)");
        names.add("Number of regular groups (negative)");
        names.add("Number of singular groups (negative)");
        names.add("Difference for regular groups");
        names.add("Difference for singular groups");
        names.add("Percentage of regular groups (positive)");
        names.add("Percentage of singular groups (positive)");
        names.add("Percentage of regular groups (negative)");
        names.add("Percentage of singular groups (negative)");
        names.add("Difference for regular groups %");
        names.add("Difference for singular groups %");
        names.add("Number of regular groups (positive for all flipped)");
        names.add("Number of singular groups (positive for all
flipped)");
        names.add("Number of regular groups (negative for all flipped)");
        names.add("Number of singular groups (negative for all
flipped)");
        names.add("Difference for regular groups (all flipped)");
        names.add("Difference for singular groups (all flipped)");
        names.add("Percentage of regular groups (positive for all
flipped)");
        names.add("Percentage of singular groups (positive for all
flipped)");
        names.add("Percentage of regular groups (negative for all
flipped)");
```

```
        names.add("Percentage of singular groups (negative for all
flipped)");
        names.add("Difference for regular groups (all flipped) %");
        names.add("Difference for singular groups (all flipped) %");
        names.add("Total number of groups");
        names.add("Estimated percent of flipped pixels");
        names.add("Estimated message length (in percent of pixels)(p)");
        names.add("Estimated message length (in bytes)");
        return names.elements();
    }

    /**
     * Gets the variation of the blocks of data. Uses the formula f(x) =
|x0 -
     * x1| + |x1 + x3| + |x3 - x2| + |x2 - x0|; However, if the block is
not in
     * the shape 2x2 or 4x1, this will be applied as many times as the
block can
     * be broken up into 4 (without overlaps).
     *
     * @param block The block of data (in 24 bit colour).
     * @param colour The colour to get the variation of.
     * @return The variation in the block.
     */
    private double getVariation(int[] block, int colour) {
        double var = 0;
        int colour1, colour2;
        for (int i = 0; i < block.length; i = i + 4) {
            colour1 = getPixelColour(block[0 + i], colour);
            colour2 = getPixelColour(block[1 + i], colour);
            var += Math.abs(colour1 - colour2);
            colour1 = getPixelColour(block[3 + i], colour);
            colour2 = getPixelColour(block[2 + i], colour);
            var += Math.abs(colour1 - colour2);
            colour1 = getPixelColour(block[1 + i], colour);
            colour2 = getPixelColour(block[3 + i], colour);
            var += Math.abs(colour1 - colour2);
            colour1 = getPixelColour(block[2 + i], colour);
            colour2 = getPixelColour(block[0 + i], colour);
            var += Math.abs(colour1 - colour2);
        }
        return var;
    }
```

```
    /**
     * Gets the negative variation of the blocks of data. Uses the
formula f(x)
     * = |x0 - x1| + |x1 + x3| + |x3 - x2| + |x2 - x0|; However, if the
block is
     * not in the shape 2x2 or 4x1, this will be applied as many times as
the
     * block can be broken up into 4 (without overlaps).
     *
     * @param block The block of data (in 24 bit colour).
     * @param colour The colour to get the variation of.
     * @param mask The negative mask.
     * @return The variation in the block.
     */
    private double getNegativeVariation(int[] block, int colour, int[]
mask) {
        double var = 0;
        int colour1, colour2;
        for (int i = 0; i < block.length; i = i + 4) {
            colour1 = getPixelColour(block[0 + i], colour);
            colour2 = getPixelColour(block[1 + i], colour);
            if (mask[0 + i] == -1) {
                colour1 = invertLSB(colour1);
            }
            if (mask[1 + i] == -1) {
                colour2 = invertLSB(colour2);
            }
            var += Math.abs(colour1 - colour2);

            colour1 = getPixelColour(block[1 + i], colour);
            colour2 = getPixelColour(block[3 + i], colour);
            if (mask[1 + i] == -1) {
                colour1 = invertLSB(colour1);
            }
            if (mask[3 + i] == -1) {
                colour2 = invertLSB(colour2);
            }
            var += Math.abs(colour1 - colour2);

            colour1 = getPixelColour(block[3 + i], colour);
            colour2 = getPixelColour(block[2 + i], colour);
            if (mask[3 + i] == -1) {
                colour1 = invertLSB(colour1);
            }
```

```java
            if (mask[2 + i] == -1) {
                colour2 = invertLSB(colour2);
            }
            var += Math.abs(colour1 - colour2);

            colour1 = getPixelColour(block[2 + i], colour);
            colour2 = getPixelColour(block[0 + i], colour);
            if (mask[2 + i] == -1) {
                colour1 = invertLSB(colour1);
            }
            if (mask[0 + i] == -1) {
                colour2 = invertLSB(colour2);
            }
            var += Math.abs(colour1 - colour2);
        }
        return var;
    }

    /**
     * Gets the given colour value for this pixel.
     *
     * @param pixel The pixel to get the colour of.
     * @param colour The colour to get.
     * @return The colour value of the given colour in the given pixel.
     */
    public int getPixelColour(int pixel, int colour) {
        if (colour == RSAnalysis.ANALYSIS_COLOUR_RED) {
            return getRed(pixel);
        } else if (colour == RSAnalysis.ANALYSIS_COLOUR_GREEN) {
            return getGreen(pixel);
        } else if (colour == RSAnalysis.ANALYSIS_COLOUR_BLUE) {
            return getBlue(pixel);
        } else {
            return 0;
        }
    }

    /**
     * Flips a block of pixels.
     *
     * @param block The block to flip.
     * @param mask The mask to use for flipping.
     * @return The flipped block.
     */
```

```java
private int[] flipBlock(int[] block, int[] mask) {
    //if the mask is true, negate every LSB
    for (int i = 0; i < block.length; i++) {
        if ((mask[i] == 1)) {
            //get the colour
            int red = getRed(block[i]), green = getGreen(block[i]),
                    blue = getBlue(block[i]);

            //negate their LSBs
            red = negateLSB(red);
            green = negateLSB(green);
            blue = negateLSB(blue);

            //build a new pixel
            int newpixel = (0xff << 24) | ((red & 0xff) << 16)
                    | ((green & 0xff) << 8) | ((blue & 0xff));

            //change the block pixel
            block[i] = newpixel;
        } else if (mask[i] == -1) {
            //get the colour
            int red = getRed(block[i]), green = getGreen(block[i]),
                    blue = getBlue(block[i]);

            //negate their LSBs
            red = invertLSB(red);
            green = invertLSB(green);
            blue = invertLSB(blue);

            //build a new pixel
            int newpixel = (0xff << 24) | ((red & 0xff) << 16)
                    | ((green & 0xff) << 8) | ((blue & 0xff));

            //change the block pixel
            block[i] = newpixel;
        }
    }
    return block;
}

/**
 * Negates the LSB of a given byte (stored in an int).
 *
 * @param abyte The byte to negate the LSB of.
```

```
     * @return The byte with negated LSB.
     */
    private int negateLSB(int abyte) {
        int temp = abyte & 0xfe;
        if (temp == abyte) {
            return abyte | 0x1;
        } else {
            return temp;
        }
    }

    /**
     * Inverts the LSB of a given byte (stored in an int).
     *
     * @param abyte The byte to flip.
     * @return The byte with the flipped LSB.
     */
    private int invertLSB(int abyte) {
        if (abyte == 255) {
            return 256;
        }
        if (abyte == 256) {
            return 255;
        }
        return (negateLSB(abyte + 1) - 1);
    }

    /**
     * Inverts a mask.
     *
     * @param mask The mask to invert.
     * @return The flipped mask.
     */
    private int[] invertMask(int[] mask) {
        for (int i = 0; i < mask.length; i++) {
            mask[i] = mask[i] * -1;
        }
        return mask;
    }

    /**
     * A small main method that will print out the message length in
percent of
     * pixels.
```

```
     *
     */
    public static void main(String[] args) {
        if (args.length != 1) {
            System.out.println("Usage: 
invisibleinktoolkit.benchmark.RSAnalysis <imagefilename>");
            System.exit(1);
        }
        try {
            System.out.println("\nRS Analysis results");
            System.out.println("-------------------");
            RSAnalysis rsa = new RSAnalysis(2, 2);
            BufferedImage image = ImageIO.read(new File(args[0]));
            double average = 0;
            double[] results = rsa.doAnalysis(image, 
RSAnalysis.ANALYSIS_COLOUR_RED, true);
            System.out.println("Result from red: " + results[26]);
            average += results[26];
            results = rsa.doAnalysis(image, 
RSAnalysis.ANALYSIS_COLOUR_GREEN, true);
            System.out.println("Result from green: " + results[26]);
            average += results[26];
            results = rsa.doAnalysis(image, 
RSAnalysis.ANALYSIS_COLOUR_BLUE, true);
            System.out.println("Result from blue: " + results[26]);
            average += results[26];
            average = average / 3;
            System.out.println("Average result: " + average);
            System.out.println();

            List<String> result_names = 
Collections.list(rsa.getResultNames());
            for (int i = 0; i < results.length; i++) {
                System.out.println(result_names.get(i) + ": " + 
results[i]);
            }

        } catch (Exception e) {
            System.out.println("ERROR: Cannot process that image type, 
please try another image.");
            e.printStackTrace();
        }
    }
```

```
    //VARIABLES
    /**
     * Denotes analysis to be done with red.
     */
    public static final int ANALYSIS_COLOUR_RED = 0;

    /**
     * Denotes analysis to be done with green.
     */
    public static final int ANALYSIS_COLOUR_GREEN = 1;

    /**
     * Denotes analysis to be done with blue.
     */
    public static final int ANALYSIS_COLOUR_BLUE = 2;

    /**
     * The mask to be used for the pixel groups.
     */
    private int[][] mMask;

    /**
     * The x length of the mask.
     */
    private int mM;

    /**
     * The y length of the mask.
     */
    private int mN;

}
//end of class
```

PixelBenchmark.java

```
/*
 *    Digital Invisible Ink Toolkit
 *    Copyright (C) 2005  K. Hempstalk
 *
 *    This program is free software; you can redistribute it and/or
modify
 *    it under the terms of the GNU General Public License as published
by
```

```
 *    the Free Software Foundation; either version 2 of the License, or
 *    (at your option) any later version.
 *
 *    This program is distributed in the hope that it will be useful,
 *    but WITHOUT ANY WARRANTY; without even the implied warranty of
 *    MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
 *    GNU General Public License for more details.
 *
 *    You should have received a copy of the GNU General Public License
 *    along with this program; if not, write to the Free Software
 *    Foundation, Inc., 675 Mass Ave, Cambridge, MA 02139, USA.
 *
 *
 *         @author Kathryn Hempstalk
 */


/**
 * A convience class to provide all the base methods
 * for benchmarkers to use.
 *
 * Provides pixel functions commonly used in benchmarking.
 *
 * @author Kathryn Hempstalk.
 */
public class PixelBenchmark{

     /**
      * Gets the red content of a pixel.
      *
      * @param pixel The pixel to get the red content of.
      * @return The red content of the pixel.
      */
     public int getRed(int pixel){
          return ((pixel >> 16) & 0xff);
     }

     /**
      * Gets the green content of a pixel.
      *
      * @param pixel The pixel to get the green content of.
      * @return The green content of the pixel.
      */
     public int getGreen(int pixel){
```

```
            return ((pixel >> 8) & 0xff);
      }

      /**
       * Gets the blue content of a pixel.
       *
       * @param pixel The pixel to get the blue content of.
       * @return The blue content of the pixel.
       */
      public int getBlue(int pixel){
            return (pixel & 0xff);
      }

}
//end of class.
```

AUMP

aump.m

```
function beta = aump(X,m,d)
%
% AUMP LSB detector as described by L. Fillatre, "Adaptive Steganalysis
of
% Least Significant Bit Replacement in Grayscale Natural Images", IEEE
% TSP, October 2011.
%
% X = image to be analyzed
% m = pixel block size
% d = q - 1 = polynomial degree for fitting (predictor)
% beta = \hat{\Lambda}^\star(X) detection statistic
%

X = double(X);
[Xpred,~,w] = Pred_aump(X,m,d);       % Polynomial prediction, w =
weights
r = X - Xpred;                        % Residual
Xbar = X + 1 - 2 * mod(X,2);          % Flip all LSBs
beta = sum(sum(w.*(X-Xbar).*r));      % Detection statistic


function [Xpred,S,w] = Pred_aump(X,m,d)
%
% Pixel predictor by fitting local polynomial of degree d = q - 1 to
```

```
% m pixels, m must divide the number of pixels in the row.
% OUTPUT: predicted image Xpred, local variances S, weights w.
%
% Implemention follows the description in: L. Fillantre, "Adaptive
% Steganalysis of Least Significant Bit Replacement in Grayscale Images",
% IEEE Trans. on Signal Processing, 2011.
%

sig_th = 1;                 % Threshold for sigma for numerical stability
q = d + 1;                  % q = number of parameters per block
Kn = numel(X)/m;            % Number of blocks of m pixels
Y = zeros(m,Kn);            % Y will hold block pixel values as columns
S = zeros(size(X));         % Pixel variance
Xpred = zeros(size(X));     % Predicted image

H = zeros(m,q);             % H = Vandermonde matrix for the LSQ fit
x1 = (1:m)/m;
for i = 1 : q, H(:,i) = (x1').^(i-1); end

for i = 1 : m               % Form Kn blocks of m pixels (row-wise) as
    aux = X(:,i:m:end);     % columns of Y
    Y(i,:) = aux(:);
end

p = H\Y;                    % Polynomial fit
Ypred = H*p;                % Predicted Y

for i = 1 : m               % Predicted X
    Xpred(:,i:m:end) = reshape(Ypred(i,:),size(X(:,i:m:end))); % Xpred =
l_k in the paper
end

sig2 = sum((Y - Ypred).^2) / (m-q);            % sigma_k_hat in the paper
(variance in kth block)
sig2 = max(sig_th^2 * ones(size(sig2)),sig2); % Assuring numerical
stability
% le01 = find(sig2 < sig_th^2);
% sig2(le01) = (0.1 + sqrt(sig2(le01))).^2;   % An alternative way of
"scaling" to guarantee num. stability

Sy = ones(m,1) * sig2;                         % Variance of all pixels
(order as in Y)

for i = 1 : m               % Reshaping the variance Sy to size of X
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    S(:,i:m:end) = reshape(Sy(i,:),size(X(:,i:m:end)));
end

s_n2 = Kn / sum(1./sig2);                    % Global variance
sigma_n_bar_hat^2 in the paper
w = sqrt( s_n2 / (Kn * (m-q)) ) ./ S;        % Weights
```

main.m

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% Загрузка и подготовка изображения
img_path = '14.bmp'; % Укажите путь к вашему изображению
X = imread(img_path);

% Если изображение цветное, преобразуем в градации серого
if size(X, 3) == 3
    X = rgb2gray(X);
end

m=16
d=2

% Вызов функции aump с параметрами m=16, d=2
beta = aump(X, m, d);

% Вывод результата
fprintf('Detection statistic beta = %.4f\n', beta);
```