**EE 5351 Digital Video Coding
Fall 2012**

**Instructor:** K.R. Rao

**Office Number:** Room 530 NH

 Electrical Engineering, Box 19016, UTA, Arlington TX 76019

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**Office Hours:** Monday, 11a.m. – 12 noon
 Wednesday 2 p.m. – 3 p.m.

**Section Information**: EE 5351, Sections 001, and 002

**Time and Place of Class Meetings:** Tu Th 2:00-3:20pm

 NH 109

**Description of Course Content:**

The course covers the fundamentals, principles, concepts and techniques of data

(video/audio) compression such as:

\* Huffman coding

\* Arithmetic coding

\* Lempel-Ziv coding

\* G3 and G4 Facsimile coding

\* Scalar quantization

* Differential pulse code modulation
* Delta modulation
* Mathematical preliminaries for lossy coding
* Mathematical preliminaries for transforms, subbands and wavelets

\* Subband coding

\* Transform coding

\* Hybrid (mixed) coding

\* Brief introduction to ITU/ISO/IEC standards related to audio/video/image/data compression

\* Vector quantization

* Motion estimation and motion compensation
* Wavelet- based compression
* Analysis/synthesis schemes
* Video compression

**Student Learning Outcomes:**

The goals of the course are to familiarize the students with the topic so that they have not only a thorough grasp but also the ability to implement them through computer projects (simulation) using standard test sequences.

**Course WWW site:** http://www-ee.uta.edu/dip/Courses/ee5351.htm

**Required Textbook(s):**

K. Sayood, "Introduction to data compression," III Edition, San Francisco, CA Morgan-Kaufmann Publishers, 2006.

**Reference**:

* V. Bhaskaran and K. Konstantinides, "Image video compression standards: algorithms and architecture," II Edition, Norwell, MA: Kluwer Academic Publishers, 1998.
* Several books related to digital video coding are on 3 hour reserve in SEL
* O. Marques, “Practical image and video processing using MATLAB, Hoboken NJ: Wiley, 2011.

**Descriptions of major assignments and examinations:**

# Introduction

 Compression Techniques…………………………………………………

 Lossless Compression……………………………………………

 Lossy Compression……………………………………………..

 Measures of Performance………………………………………

 Modeling and Coding…………………………………………………..

 Coding…………………………………………………………………

 Uniquely Decodable Codes……………………………………

 Prefix Codes…………………………………………………..

## Huffman Coding

 Overview………………………………………………………………

 The Huffman Coding Agorithm………………………………………..

 Minimum Variance Huffman Codes…………………….…….

 Golomb Codes………………………………………………………..

 Rice Codes……………………………………………………….……

 CCSDS Recommendation for Lossless Compression…….……

 Tunstall Codes………………………………………………………..

 Application of Huffman Coding………………………………………

 Lossless Image Compression…………………………………..

 Text Compression……………………………………………..

 Audio Compression……………………………………………………

## Arithmetic Coding

 Overview……………………………………………………………….

 Introduction…………………………………………………………….

 Coding a Sequence…………………………………………………….

 Generating a Tag……………………………………………….

 Deciphering a Tag……………………………………….……..

 Generating a Binary Code……………………………………….……..

 Uniqueness and Efficiency of the Arithmetic Code……………

 Algorithm Implementation……………………………………..

 Integer Implementation…………………………………………

 Comparison of Huffman and Arithmetic coding……………………….

 Applications……………………………………………………………

 Bi-level Image Compression-The JBIG Standard…………….

 JBIG2…………………………………………………….…….

 Image Compression…………………………………………..

**Dictionary Techniques**

 Overview……………………………………………………………….

 Introduction…………………………………………………………….

 Static Dictionary………………………………………………………..

 The LZ77 Approach……………………………………………

 The LZ78 Approach……………………………………………..

 Applications……………………………………………………….…….

 File Compression-UNIX Compress……………………………...

 Image Compression-The Graphics Interchange Format (GIF)…..

 Compression over Modems-V.42 bis……………………………

# Predictive Coding

#  Overview………………………………………………………………

 Introduction…………………………………………………………..

 Prediction with Partial March (*ppm*)…………………………………

 The Basic Algorithm………………………………………….

 The Escape Symbol…………………………………………..

 Length of Context…………………………………………….

 The Exclusion Principle……………………………………….

 The Burrows-Wheeler Transform……………………………………..

 Move-to-Front Coding…………………………………………

 CALIC…………………………………………………………………

 JPEG-LS……………………………………………………………….

 “Current” Standard…………………………………………….

 “New” Standard………………………………………………..

 Multiresolution Approaches……………………………………………

 Progressive Image Transmission……………………………….

 Facsimile Encoding…………………………………………………….

 Run-Length Coding…………………………………………….

 CCITT Group 3 and 4-Recommendation T.4

 and T.6…………………………………………………………..

 Comparison of MH, MMR, and JBIG…………………………..

 Dynamic Markov Compression…………………………………………

## Scalar Quantization

 Overview…………………………………………………………………

 Introduction………………………………………………………………

 The Quantization Problem………………………………………………..

 Uniform Quantizer………………………………………………………..

 Adaptive Quantization……………………………………………………

 Forward Adaptive Quantization…………………………………..

 Backward Adaptive Quantization…………………………………

 Nonuniform Quantization…………………………………………………

 *Pdf-* Optimized Quantization………………………………………

 Companded Quantization………………………………………….

 Entropy-Coded Quantization……………………………………………… Entropy Coding of Lloyd-Max Quantizer Outputs………………………………

## Vector Quantization

 Overview…………………………………………………………………..

 Introduction………………………………………………………………..

 Advantages of Vector Quantization over Scalar Quantization…………….

 The Linde-Buzo-Gray Algorithm………………………………………….

 Initializing the LBG Algorithm…………………………………….

 The Empty Cell Problem…………………………………………..

 Use of LBG for Image Compression………………………………

 Tree-Structured Vector Quantizers…………………………………………

 Design of Tree-Structured Vector Quantizers………………………

 Pruned Tree-Structured Vector Quantizers…………………………

 Structured Vector Quantizers………………………………………………..

 Pyramid Vector Quantization………………………………………..

 Polar and Spherical Vector Quantizers………………………………

 Latice Vector Quantizers…………………………………………….

 Variations on the Theme……………………………………………………..

 Gain-Shape Vector Quantization…………………………………….

 Mean-Removed Vector Quantization………………………………..

 Classified Vector Quantization………………………………………

 Multistage Vector Quantization………………………………………

 Adaptive Vector Quantization………………………………………..

 Trellis-Coded Quantization…………………………………………………..

## Differential Encoding

 Overview……………………………………………………………………..

 Introduction…………………………………………………………………..

 The Basic Algoithm………………………………………………………….

 Prediction in DPCM………………………………………………………….

 Adaptive DPCM………………………………………………………………

 Adaptive Quantization in DPCM……………………………………...

 Adaptive Prediction in DPCM…………………………………………

 Delta Modulation………………………………………………………………

 Constant Factor Adaptive Delta Modulation (CFDM)………………..

 Continuously Variable Slope Delta Modulation………………………

 Speech Coding…………………………………………………………………

 G.726………………………………………………………………….

 Image Coding…………………………………………………………………..

## Transform Coding

 Overview……………………………………………………………………

 Introduction…………………………………………………………………

 The Transform………………………………………………………………

 Transform of Interest……………………………………………………….

 Karhunen-Loeve Transform ……………………………………….

 Discrete Cosine Transform…………………………………………

 Discrete Walsh-Hadamard Transform………………………………

 Quantization and Coding of Transform Coefficients……………………….

 Application to Image Compression-JPEG………………………………….

 The Transform………………………………………………………

 Quatization………………………………………………………….

 Coding………………………………………………………………

 Application to Audio Compression…………………………………………

## Subband Coding

 Overview…………………………………………………………………..

 Introduction……………………………………………………………….. Filters………………………………………………………………………

 Some Filters Used in Subband Coding……………………………

 The Basic Subband Coding Algorithm……………………………………

 Anaysis……………………………………………………………

 Quantization and Coding………………………………………….

 Synthesis…………………………………………………………..

 Design of Filter Banks \*…………………………………………………

 Downsampling \*…………………………………………………

 Upsampling \*……………………………………………………..

 Perfect Reconstruction Using Two-Channel Filter Banks \*………………

 Two-Channel PR Quandrature Mirror Filters \*………………….

 Bit Allocation………………………………………………………………

 Application to Speech Coding-G.722……………………………………..

 Application to Audio Coding-MPEG Audio………………………………

 Application to Image Compression………………………………………..

 Decomposing and Image…………………………………………..

 Coding the Subbands………………………………………………

## Wavelet-Based Compression

 Overview………………………………………………………………….

 Introduction……………………………………………………………….

 Wavelets………………………………………………………………….

 Multiresolution Analysis and the Scaling Function………………………

 Implementation Using Filters…………………………………………….

 Scaling and Wavelet Coefficients………………………………..

 Families of Wavelets………………………………………………

 Image Compression……………………………………………………….

 Embedded Zerotree Coder………………………………………………..

 Set Partitioning in Hierarchical Trees……………………………………..

 JPEG 2000…………………………………………………………………

## Analysis/Synthesis Schemes

 Overview…………………………………………………………………..

 Introduction………………………………………………………………...

 Speech Compression…………………………………………………….…

 The Channel Vocoder……………………………………………..

 The Linear Predictive Coder (Government Standard LPC-10)……

 Code Excited Linear Prediction (CELP)…………………………..

 Sinusoidal Coders……………………………………………….

 Image Compression………………………………………………………..

 Fractal Compression……………………………………………….

## Video Compression

 Overview……………………………………………………………………

 Introduction…………………………………………………………………

 Motion Compensation………………………………………………………

 Video Signal Representation………………………………………………..

 Algorithms for Videoconferencing and Videophones………………………

 ITU-T Recommendation H.261……………………………………..

 Model-Based Coding………………………………………………..

 Asymmetric Application……………………………………………………..

 The MPEG-1 Video Standard………………………………………..

 The MPEG-2 Video Standard……………………………………….

 MPEG-4……………………………………………………………..

 MPEG-7……………………………………………………………..

**Projects**

Project 1. Huffman Coding

 Project 2. Golomb Coding

 Project 3. LZ-77 Algorithm

 Project 4. Scalar Quantization

 Project 5. Vector Quantization

 Project 6. DPCM

 Project 7. Subband Analysis/Synthesis

 Project 8. JPEG-Baseline

 Project 9. JPEG-lossless

 Project10. JPEG-LS (LOCO)

Project11. CALIC

 Project12. HINT

 Project13. 16\*16 Intra Prediction

 Project14. Digital Watermarking

 Project15. 1:2 Sub sampling and 2:1 Up sampling

# Attendance: Follow university guidelines.

**Grading**:

**PLAN A**

Test 1 15% A=90-100%
Test 2 15% B=80-89%
Final 20% C=70-79%
Design projects 50% D=60-69%

**PLAN B:**

**(For those who miss a test – not recommended)**

Max of Test 1 and Test 2: 25%, Final: 25%, Design projects; 50%

Course grades are based on max. of Plan A and Plan B, whichever is higher.

Grades are based on the student’s performance in the course and nothing else. This includes tests/projects etc based on the grading formula - all described in detail in the course web site. This format is universal and applies equally to all students.

Please do not ask

1.       “I will do additional work/project etc to improve my course grade after the grades are assigned.”

2.       My GPA is low and I need an A to avoid probation etc.

3.       I must graduate this semester and the only way is to get grade A.

4.       My grades in TPC are low and I need an A.

       5. Any other excuse.

Students are expected to keep track of their performance throughout the semester and seek guidance from available sources (including the instructor) if their performance drops below satisfactory levels.

**Everyone must take the final.**

1. No makeup. 2. No incomplete. Final exam papers will not be returned. The student, however, has the right to look at his/her exam paper and discuss it with the instructor. If the student has questions/clarifications regarding the returned tests, this needs to be taken care of within a week from the dates of returns. Final exam papers will be kept until the midsemester of the following long semester. (No telephone calls or inquiries regarding course grades, please.) Everyone must take the tests and final exam at the same time and at the same place. If you have any questions on your returned tests, please do so within a week. Per the DE policy, the distance education students are supposed to have a 24hr window to take their exams. This time frame is to accommodate working students and students located in different time zones. Contact: Engineering center for distance education (Room 242 Nedderman Hall): Donya (phone: 1-817-272-2352, email: drandolph@uta.edu Fax; 1-817-272-5630). For other technical concerns on video lectures please contact etv.problems@engineering.uta.edu

**Make-up Exams**: None

**Grade Grievances**: It is the obligation of the student, in attempting to resolve any student grievance regarding grades, first to make a serious effort to resolve the matter with the instructor with whom the grievance originated. Individual instructors retain primary responsibility for assigning grades. The instructor's judgment is final unless compelling evidence shows preferential treatment or procedural irregularities. If students wish to appeal, their requests must be submitted in writing on an Academic Grievance Form available in departmental or program offices to the department chair or program director. Before considering a grievance, the department chair or program director will refer the issue to a departmental or program committee of graduate faculty. If the committee cannot reach a decision acceptable to the parties involved, the department chair or program director will issue a decision on the grievance. If students are dissatisfied with the chair or director's decision, they may appeal the case to the academic dean. If they are dissatisfied with the academic dean's decision, they may appeal it to the Dean of Graduate Studies. Students have one year from the day grades are posted to initiate a grievance concerning a grade.

**Drop Policy:** Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (<http://wweb.uta.edu/ses/fao>).

**Americans with Disabilities Act:** The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the *Americans with Disabilities Act (ADA)*. All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at [www.uta.edu/disability](http://www.uta.edu/disability) or by calling the Office for Students with Disabilities at (817) 272-3364.

**Academic Integrity**: All students enrolled in this course are expected to adhere to the UT Arlington Honor Code:

*I pledge, on my honor, to uphold UT Arlington’s tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.*

*I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.*

Instructors may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents’ Rule* 50101, §2.2, suspected violations of university’s standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student’s suspension or expulsion from the University.

**Student Support Services**:UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at [www.uta.edu/resources](http://www.uta.edu/resources).

**Electronic Communication:** UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at <http://www.uta.edu/oit/cs/email/mavmail.php>.

**Student Feedback Survey:** At the end of each term, students enrolled in classes categorized as lecture, seminar, or laboratory shall be directed to complete a Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student’s feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington’s effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit <http://www.uta.edu/sfs>.

**Final Review Week:** A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week *unless specified in the class syllabus*. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

**Librarian to Contact:** Sylvia George-Williams

NH - B03D
Ph: (817) - 272-7519

Email: sylvia@uta.edu

**Course Schedule.**

**First Day of Classes**: Thursday, Aug 23, 2012

**Last Date of drop**: Wednesday, Oct 31, 2012

**Last Day of Classes**: Wednesday, Dec. 5, 2012

|  |  |  |
| --- | --- | --- |
| **Project no.** | **Project title** | **Due date** |
| 1 | [Huffman coding](http://www-ee.uta.edu/dip/Courses/EE5351/Project%20One_New.doc) | Tue, Sep 4, 2012 |
| 2 | [Golomb coding](http://www-ee.uta.edu/dip/Courses/EE5351/Project%202.doc) | Tue, Sep 11, 2012 |
| 3 | [LZ-77 algorithm](http://www-ee.uta.edu/dip/Courses/EE5351/project3.doc) , [Project 3 ref](http://www-ee.uta.edu/dip/Courses/EE5351/p3ref.htm) | Tue, Sep 18, 2012 |
| 4 | [Scalar quantization](http://www-ee.uta.edu/dip/Courses/EE5351/pro4.docx) | Thurs, Sep 27, 2012 |
| 5 | [Vector quantization](http://www-ee.uta.edu/dip/Courses/EE5351/p5.htm) | Tue, Oct 2 2012 |
| 6 | [DPCM](http://www-ee.uta.edu/dip/Courses/EE5351/Project%206.pdf) | Thurs, Oct 18, 2012 |
| 7 | [Subband analysis/synthesis](http://www-ee.uta.edu/dip/Courses/EE5351/project7.doc) (updated 8/5/08) | Tue, Oct 23, 2012 |
| 8 | [JPEG-Baseline](http://www-ee.uta.edu/dip/Courses/EE5351/Project%208.doc) | Tue , Oct 30, 2012 |
| 9 | [JPEG-Lossless](http://www-ee.uta.edu/dip/Courses/EE5351/project9.doc) | Tue, Oct 30, 2012 |
| 10 | [JPEG-LS (LOCO)](http://www-ee.uta.edu/dip/Courses/EE5351/Project10.doc) | Tue, Oct 30, 2012 |
| 11 | [CALIC](http://www-ee.uta.edu/dip/Courses/EE5351/project%2011.pdf) ([hints](http://www-ee.uta.edu/dip/Courses/EE5351/pro11.docx)) | Thurs, Nov 1, 2012 |
| 12 | [HINT](http://www-ee.uta.edu/dip/Courses/EE5351/project12.pdf) | Thurs, Nov 8, 2012 |
| 13 | [16x16 Intra prediction](http://www-ee.uta.edu/dip/Courses/EE5351/Project%2013.pdf)  (added 06/22/10) | Thurs, Nov 15, 2012 **(New)** |
| 14 | [Digital watermarking](http://www-ee.uta.edu/dip/Courses/EE5351/Project%2014%20Digital%20watermarking.pdf) (added 07/09/10) | Thurs, Nov 29, 2012 **(New)** |

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| --- | --- | --- |
| 15 | [1:2 Sub sampling & 2:1 Up sampling](http://www-ee.uta.edu/dip/Courses/EE5351/project%2015.pdf)(added 08/03/10) | Tue, Dec 4, 2012 **(New)** |

**Projects delayed will be penalized by 10 points (10%) for each day.  After 10 days they will not be considered any more.**

**Test # 1**: Thursday, Sep 27, 2012
**Test # 2:** Thursday, Nov 1, 2012

 **Final:** Thursday, Dec 13, 2012

*As the instructor for this course, I reserve the right to adjust this schedule in any way that serves the educational needs of the students enrolled in this course. –K. R. Rao.*