ABSTRACT
Since there are few open image retrieval toolkits available, researchers in the field are often forced to re-implement existing algorithms in order to perform a comparative evaluation. None of the existing toolkits support retrieval of JPEG images directly in the compressed domain. The authors' aim is therefore to facilitate the use of compressed domain image retrieval techniques as well as ease retrieval evaluation by fellow researchers. For this purpose, the authors present JIRL, an open source C++ software suite that allows content-based image retrieval in the JPEG compressed domain and provides tools for benchmarking retrieval accuracy and retrieval time. In total, twelve state-of-the-art JPEG retrieval algorithms are implemented, while for each method techniques for compressed domain feature extraction as well as feature comparison are provided in an object-oriented framework. An example image retrieval application is also provided to demonstrate how the library can be used. JIRL is made available to fellow researchers under the LGPL v.2.1 license.

Keywords: Benchmarking, Compressed-Domain Retrieval, Content-Based Image Retrieval (CBIR), Image Compression, Image Databases, JPEG, Query-By-Example (QBE) Retrieval

INTRODUCTION
As image databases are continually growing, the need to search through these datasets accurately and quickly becomes increasingly more important. Content-based image retrieval (CBIR) (Smeulders, Worring, Santini, Gupta, & Jain, 2000; Datta, Joshi, Li, & Wang, 2008; Schaefer, 2011a, 2011b) provides a way to query these large image collection and retrieve images of interest based on similar visual characteristics such as similar colour, texture, shape etc.

Evaluation and benchmarking is recognised as one of the major difficulties in the development of computer vision and imaging algorithms (Klette, Stiehl, Viergever, & Vincken, 2000), and this is especially the case for CBIR (Mueller, Mueller, Squire, Marchand-Maillet, &
One particular aspect of this is the rather limited availability of implementations of existing approaches which hinders appropriate comparison of new methods with the literature. While there are a few notable exceptions, such as (Deselaers, Keysers, & Ney, 2008; Lux & Chatzichristofis, 2008; Bastan, Cam, Gudukbay, & Ulusoy, 2009), there are no open implementations of most of the published CBIR work.

In typical CBIR systems, image features for a dataset are extracted in an off-line stage, and are then loaded once and cached in a database. During retrieval, corresponding features for a query image are calculated and then compared to the features stored in the database. In contrast, in an on-line retrieval scenario (Edmundson & Schaefer, 2012a), features for database images are not available and hence have to be extracted during the retrieval process, requiring highly efficient methods to allow for interactive retrieval times.

The vast majority of images are stored in compressed form, typically in JPEG format. While CBIR feature extraction needs to be performed quickly, especially for large image datasets, this is hindered by relatively slow image decompression that needs to be employed before features can be extracted from the pixel domain. A faster approach is to perform this directly in the compressed domain, that is to perform compressed domain image retrieval (Mandal, Idris, & Panchanathan, 1999; Schaefer, 2010) and support so-called mid-stream content access (Picard, 1994).

JPEG (Wallace, 1991) is a lossy image compression technique that splits the image into blocks of 8×8 pixels and applies the discrete cosine transformation to each block. This separates high and low frequency information, making it easier to discard visually less important information in a quantisation process. After quantisation, the DC and AC coefficients are differentially respectively run-length coded, while entropy coding is applied in a final step. By working in the compressed domain of JPEG, image retrieval can be performed on the raw DCT coefficients, avoiding the computationally expensive inverse-DCT and thus yielding a significant speed-up (Edmundson & Schaefer, 2012d, 2012e).

In this paper, we present JIRL, an open source C++ library for performing compressed domain CBIR of JPEG images, originally introduced in (Edmundson & Schaefer, 2012f). JIRL contains implementations of twelve methods, representing the state-of-the-art of image retrieval in the compressed JPEG domain, and provides functionality for both feature extraction and feature comparison.

Included with the library are tools which can be used for benchmarking existing and new compressed domain techniques. The tools allow for evaluation of both retrieval performance (based on a ground truth) and an accurate speed calculation. Also included is an application that performs query-by-example (QBE) retrieval and also serves as a demonstration of the usage of the library. JIRL is distributed under a LGPL v.2.1 license and is available for download from http://gitorious.org/jirl.

**JPEG IMAGE COMPRESSION**

The JPEG standard (Wallace, 1991) defines a lossy method for compressing and decompressing images. The JPEG compression scheme is as follows:

1. **Original Image**
2. **Convert to YCC Colour Space**
3. **Split Image into Blocks of 8×8 Pixels**
4. **Discrete Cosine Transformation**
5. **Quantisation**
   - **Quantisation Table**
   - **Differential Encoding**
   - **Run-length Encoding**
6. **Huffman Coding**
7. **JPEG Image**

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**Figure 1. The JPEG compression scheme**

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Comparison of Image Decompositions Through Inverse Difference and Laplacian Pyramids


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