Real-Time Digital Image Watermarking

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Abstract

- With digital watermarking, information containing origin, status, and/or destination of the data/image, can be imperceptibly and robustly embedded in the host data/image.
- This paper describes two efficient Watermarking Algorithms using spatial domain technique and another algorithm using frequency domain approach. Both approaches are compared.
- A real-time implementation of the encoding and decoding using TI TMS320C6711 DSP is described.
- Applications of watermarking are also described.

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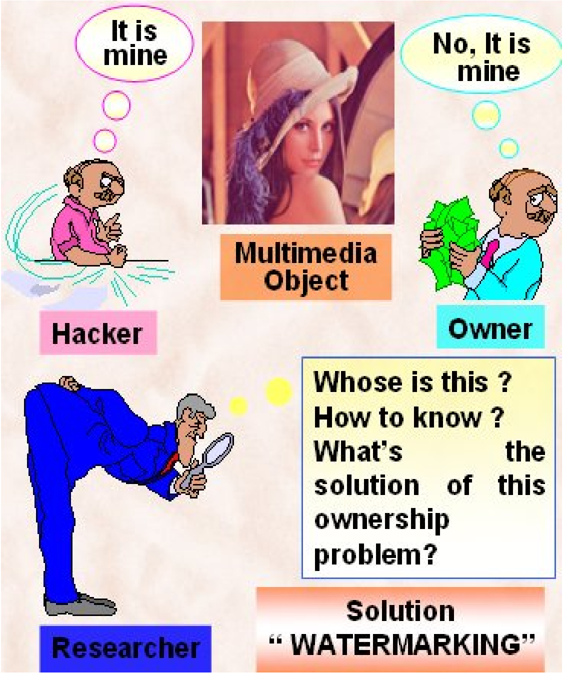
Introduction

- Digital watermarking is the process by which an image is coded with an owner's watermark
- **Add watermark sequence to the image such that:**
  - there is no perceptual degradation of the image
  - watermark should be detectable even after manipulation of image.



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Why Real-Time Implementation

- **Protection of copyright on semi-public image databases (e.g. at photo stock agencies) .**
- **Identification of photographs or video data (e.g. automatic retrieval of patient records based on a watermark embedded in an X-ray, marking of surveillance camera tapes with location and time codes to protect against tampering). .**
- **Fingerprinting or labeling**

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Why DSP?

- Fixed Point
- Speed
- Memory
- Accuracy
- Architecture Utilization
- Parallel Execution
- Optimization
- Capacity
- I/O Synchronization

TMS320C6711 DSP

- Large amount of memory
- Floating Point DSP processor
- High-performance, advanced very-long-instruction-word (VLIW) architecture developed by Texas Instruments (TI), making this DSP an excellent choice for multichannel and multifunction applications
- C6711's highly parallel architecture with the ability to run two pipelines with two different sets of data at the same time, is perfect for image processing.

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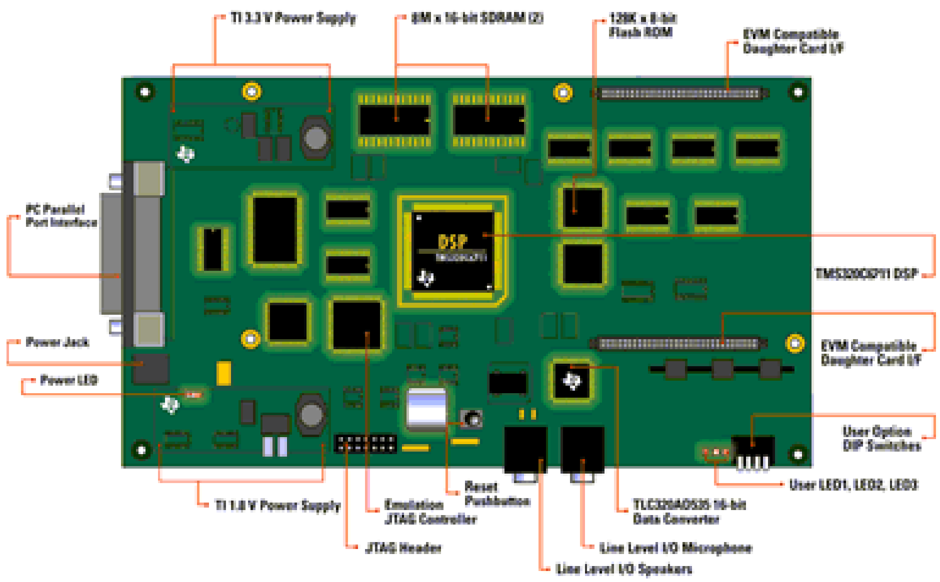
Development Phases

- **PC Application: Embedding & Detection**
- **TMS320C6711 DSP embedding implementation.**



Watermarking Techniques

- **Digital watermarking is a technique for data hiding in digital multimedia**
- **Watermarking in images should meet the next set of requirements :**
  - Invisibility to a Human Visual System Visual System
  - Robustness to various kinds of distortions
  - Simplicity of detection and extraction to the owner
  - High information capacity

Watermarking techniques (cont)

- **Watermarking techniques divided into two basic classes :**
  - Spatial Domain WM- pixels values are affected
  - Frequency Domain WM- transform coefficients are affected
- **The advantages are high robustness and exploiting the Human Visual System features**
- **The watermark is embedded using two transforms**
  - DCT based watermark
  - DFT based watermark

Frequency Domain

- First transform an image into the frequency domain.
- A block-based DCT watermarking approach is implemented.
- An image is first divided into blocks and DCT is performed on each block. The watermark is then embedded by selectively modifying the middle-frequency DCT coefficients.

STEPS

- Read the image from source and store it in an array.
- Divide the image into smaller blocks.
- Perform block image transformation (Discrete Cosine Transform).
- Divide the watermark (only 2 intensity levels) into same number of blocks as the host image.
- Count the number of occurrences of white in the watermark and sort the watermark blocks according to that.
- Find out the variance of each scanned image block and sort it according to its variance.

STEPS

- Out of each individual block select the middle frequency coefficients by scanning the block in a zig-zag manner.
- Polarity is defined as either positive or negative depending on the sign of the difference of frequency coefficient values of a pixel in a scanned block and its counterpart in another block. If the corresponding pixel in the watermark is white then, increase the coefficient value of the larger coefficient by 1.
- Assemble the blocks again and perform inverse Discrete Cosine Transform on the blocks.
- Display the watermarked image and the original image and check for discrepancies.

Details

- For example take an inbuilt Matlab image. The watermarks are generated for various testing purposes using MS Paint.
- Our original image size is 256x256. The image is divided into 8x8 blocks. Incase the image has an odd number of row column values, insert white pixels to generate row column indices which are even numbers.
- Since the image is in 2D, the transformation has to take an account of that and perform 2D DCT on the block. For testing purposes the dct2 function from the Image Processing Toolbox in Matlab has been used.
- The watermark chosen was 128x128 and it was broken down into blocks of 4x4.

Details (cont)

- We embed the watermark according to the relation between coefficient pairs in the scanned blocks. A pair of scanned blocks is a block of host image and a block that is 33 blocks ahead from it in the sorted list. In the pair of blocks, for each corresponding pixel **coefficient in the middle frequencies (i.e. the 4x4 blocks made earlier), if their difference is not equal to zero and their corresponding watermark pixel is white, then increment the higher coefficient by 1.**
- **The intent behind incrementing the higher coefficient by 1 is to not destroy the inherent inequality in the coefficient pair. This change when compared with the coefficient pair difference in the original image, helps extracting the watermark.**

Extract Watermark

- Obtain the original host image.
- Generate blocks out of it and perform DCT on them
- Similarly for the watermarked image, generate blocks and perform DCT.
- Sort the original image blocks and the watermarked blocks according to their variance.
- Now for each middle frequency coefficient blocks in the original image blocks and the watermarked blocks for the corresponding frequency coefficient pairs, if the difference is different in the original and watermarked blocks, it means that the corresponding pixel in the watermark is white else it is black
- **Thus following step 5 obtain pixel intensities and generate 4x4 watermark blocks.**
- **Assembling them together give the entire watermark**

Index of image block	Variances
4	33.2
0	30.5
3	22.2
1	16.7
2	8.2

Index of watermark block	Signed pixels No.
2	10
3	8
1	7
0	3
4	2

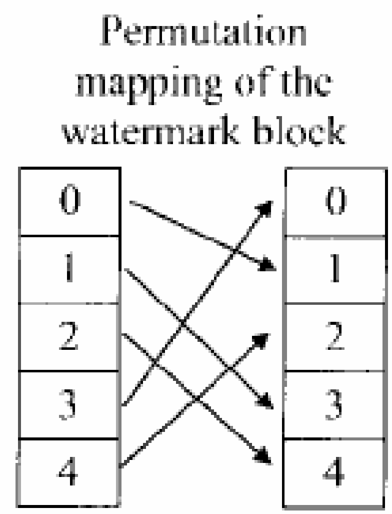


Fig. 2. Example of block-based image-dependent permutation, where for each 8×8 image block, the variance is computed and sorted, and for each watermark block of size $(M_1 \times \frac{8}{N_1}) \times (M_2 \times \frac{8}{N_2})$, the amount of information (i.e., the number of signed pixels) is sorted also, and then each watermark block is shuffled into the spatial position according the corresponding sorting order of the image.

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

→

14	15	27	16
17	25	18	24
31	19	23	32
20	22	33	21

(a) (b)

Fig. 3. Example of defining the middle-frequency coefficients, in which the coefficients are picked up in zigzag-scan order and then reordered into block of 4 × 4. (a) Zigzag ordering of DCT coefficients and the middle frequency coefficients are shown in the shadow area. (b) Picked up coefficients are mapped into the 4 × 4 block.

Watermark Embedding – Frequency Domain

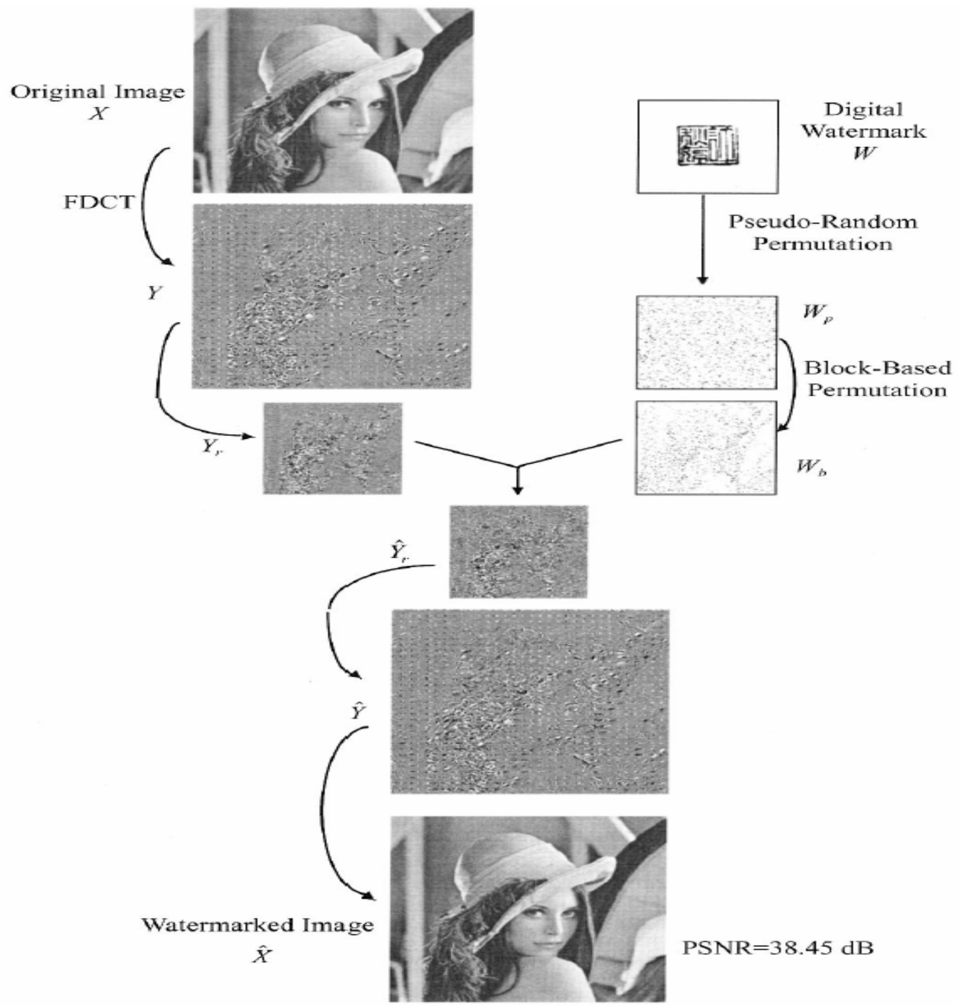


Fig. 1 Watermark embedding steps.

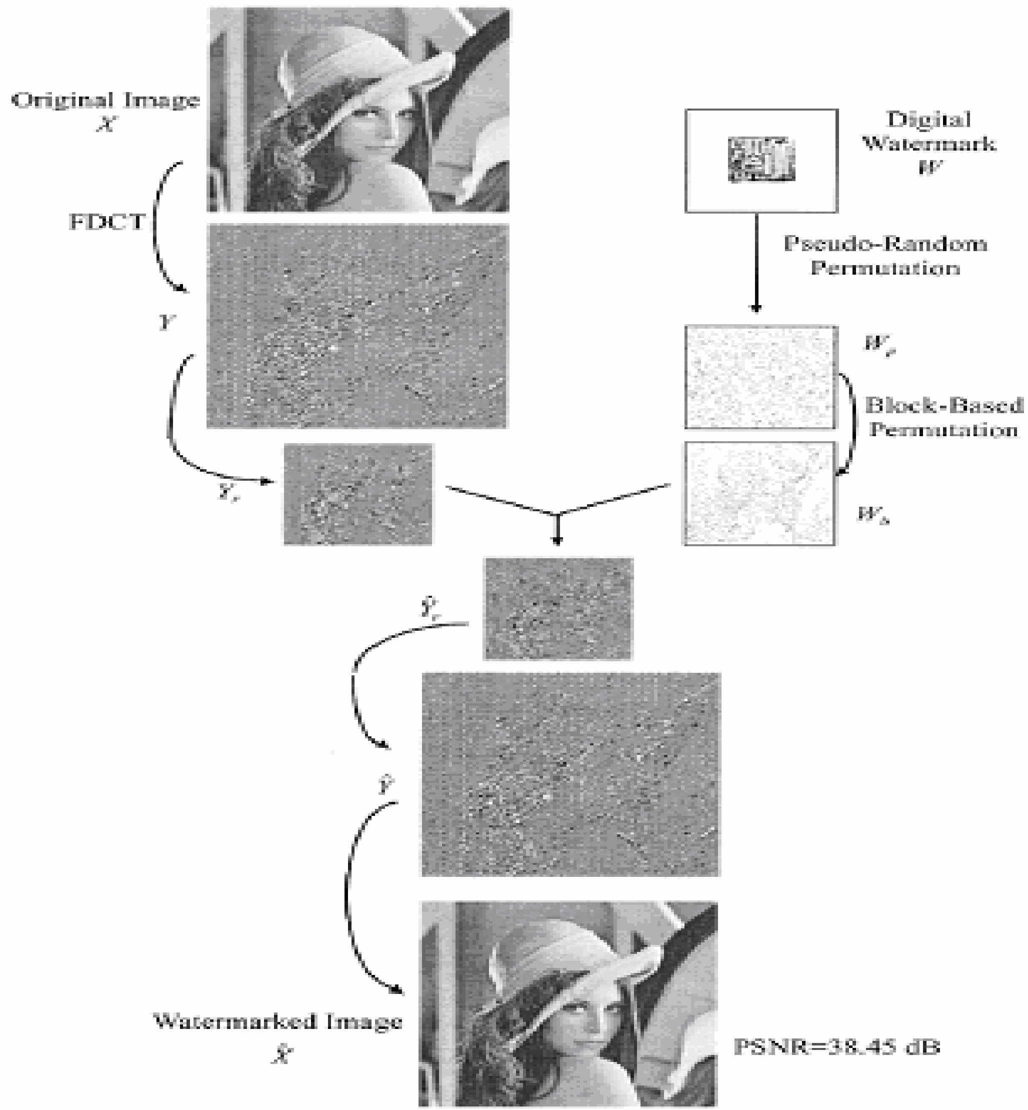
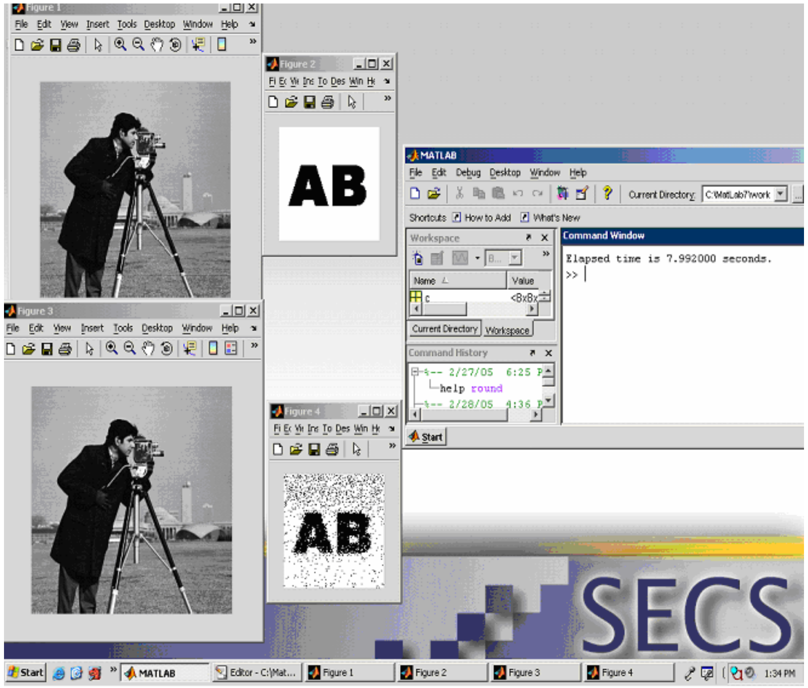


Fig. 4 Watermark embedding steps.

Results

- The algorithm executes within 7.99 secs, with only the algorithm running on the computer. The processor is a Pentium III running at 800 Mhz with 256MB RAM.
- The algorithm takes nearly 500 ms in the DSP board.



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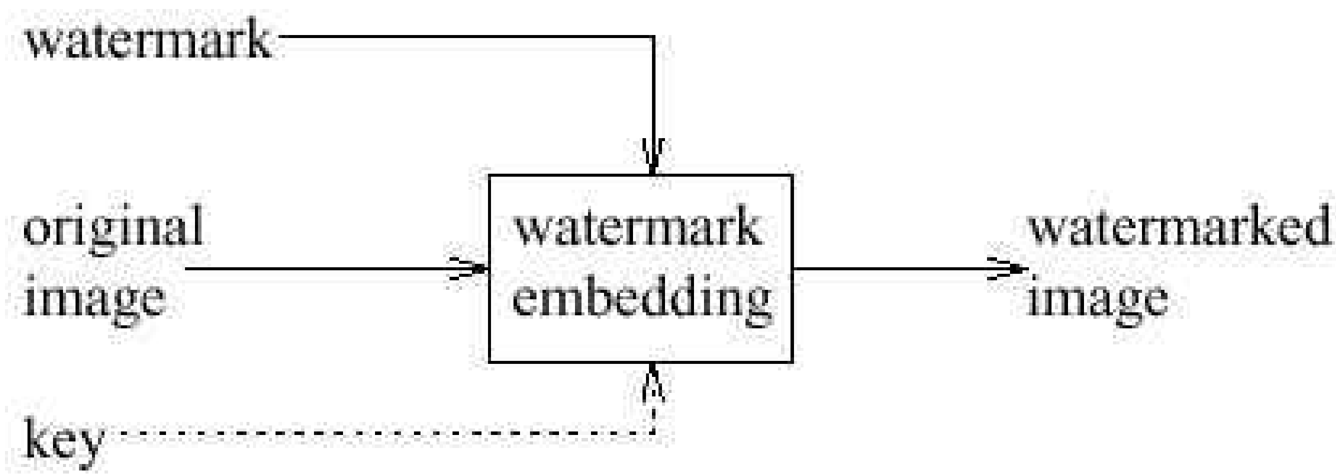
Spatial Domain Technique

- **The spatial-domain techniques directly modify the intensities or color values of some selected pixels**

- **Watermark Embedding**



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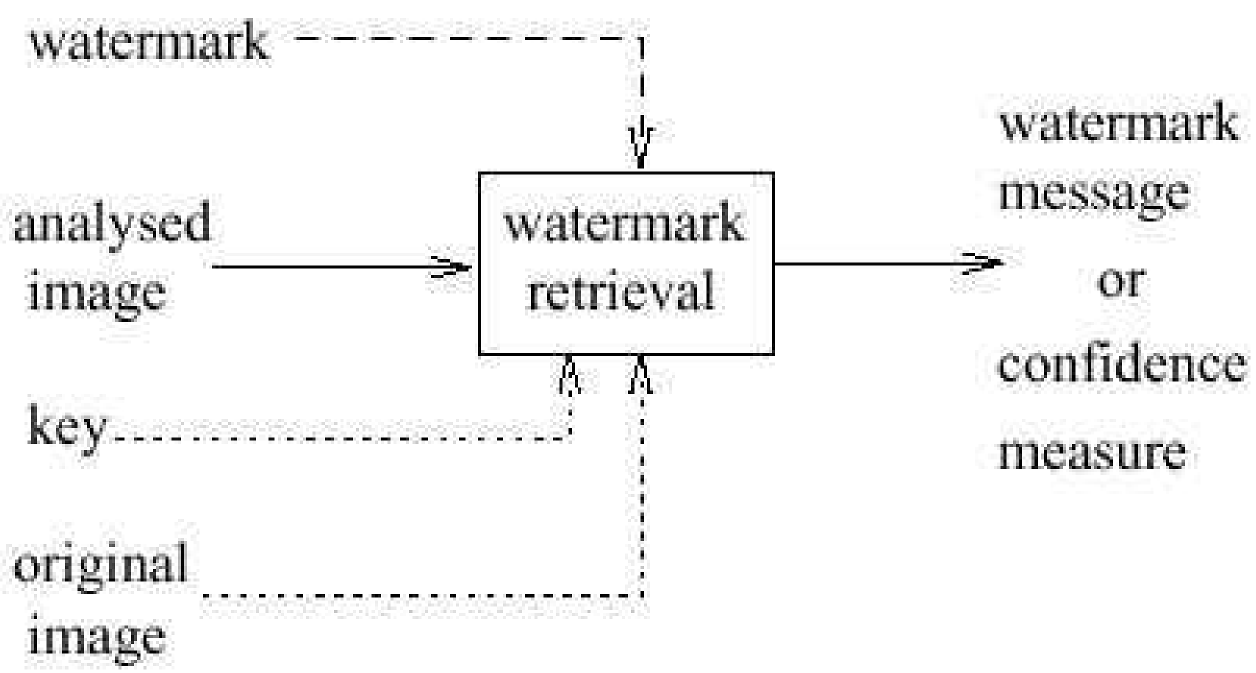
Spatial Domain Technique (cont)

- **Watermark Decoding**



Results

Input

Output

Figure 3 Original Host Image of size 128x128

Figure 4 Original Signature Image of size 64x64

Figure 4 watermarked image of size 128x128

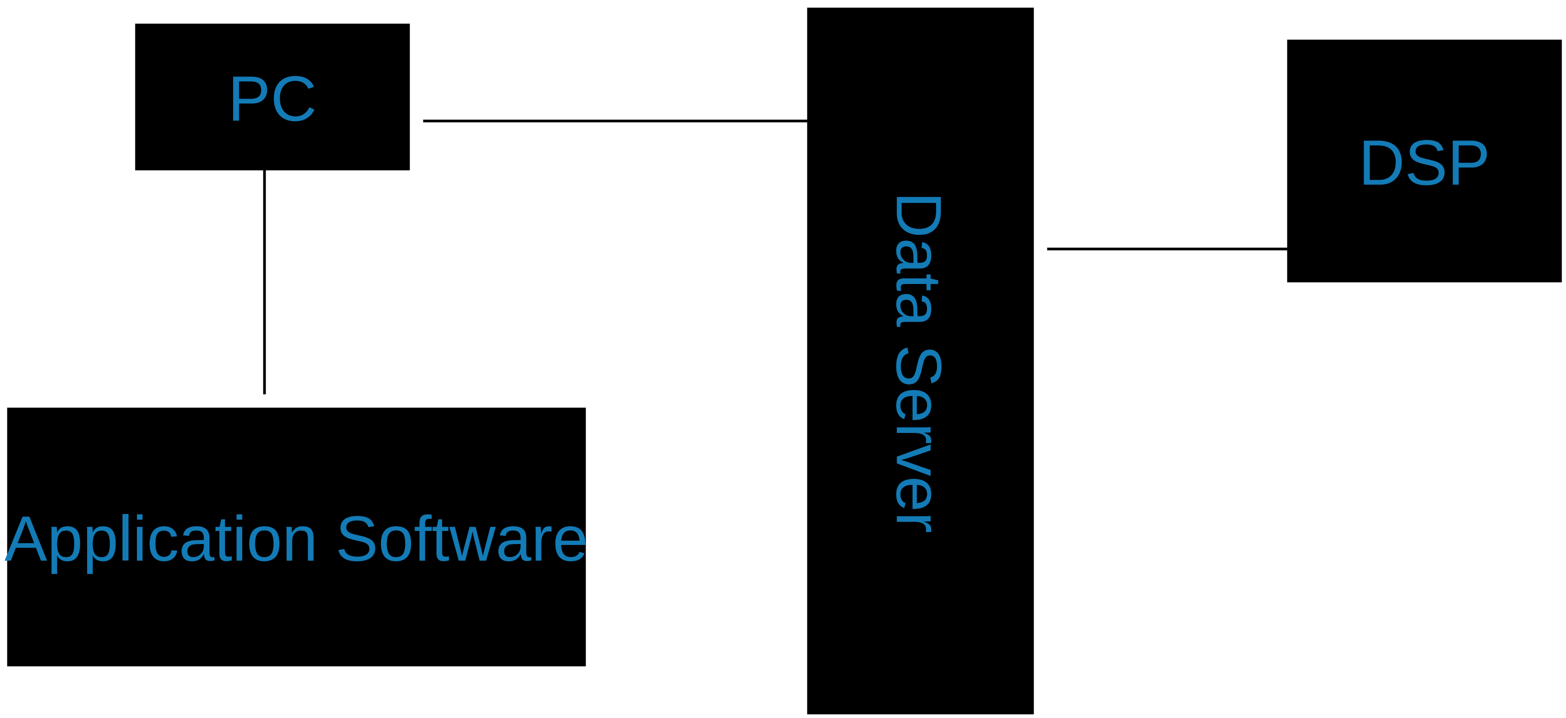
Execution Time on DSP 6711

- **Execution of code – 500 millisecond**

- **Loading of the image – 2-5 or above minutes**

  - depending on the size of the image and the memory the time for loading of the image takes.

Diagram



Applications

- Copyright Protection(Proof of Ownership)

  - To prove ownership
- Copy Control(Fingerprinting)

  - To trace illegal copies: Each copy has its own serial number

  - License agreement
- Data Authentication

  - Check if content is modified
- Data Hiding

  - Providing private secret messages
- Broadcasting Monitoring**(Internet, TV, Radio…)**

  - For commercial advertisement

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Conclusion

- Speed – 16 times faster than the PC application.
- Quality – No perceivable effect on picture quality.
- Completeness – Full DSP and HOST apps.
- Portability – Can be easily ported to any DSP processor.
- Capacity – Easily upgradeable to a Multi-channel system.
- Innovation – Non-Standardized field.
- Commercial Value – Huge potential market.

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Future Research

- Test the robustness of the watermarked Image (scaling,cropping etc) using the TMS320C6711 DSP
- Explore application of other watermarking algorithms to increase speed.

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