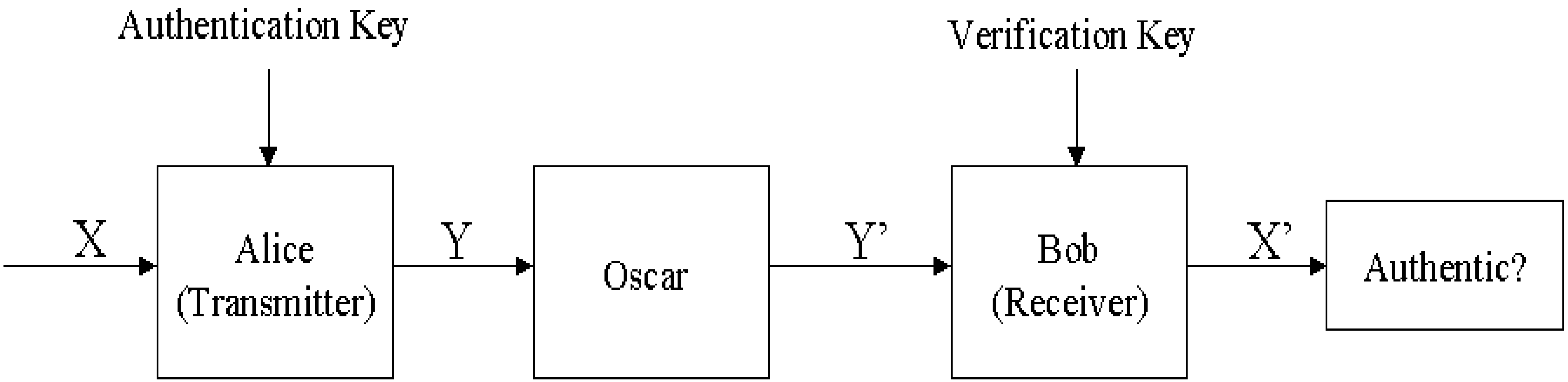
Part II

Authentication Techniques

Authentication Codes



- Provides means for ensuring integrity of message
- Independent of secrecy - in fact sometimes secrecy may be undesirable!

Techniques for Authentication

- Achieved by adding redundancy
  - authenticator, tag, etc., or
  - structure of message
- In some sense like Error Correcting Codes
- Private Key - Public Key   <=> Authentication - Digital Signature
  - Digital Signatures also provide origin authentication.
- Attacks
  - Substitution
  - Impersonation
  - Choice of above

Authenticating Multimedia Content

Proliferation of digital multimedia content

and

Ease with which digital content can be manipulated

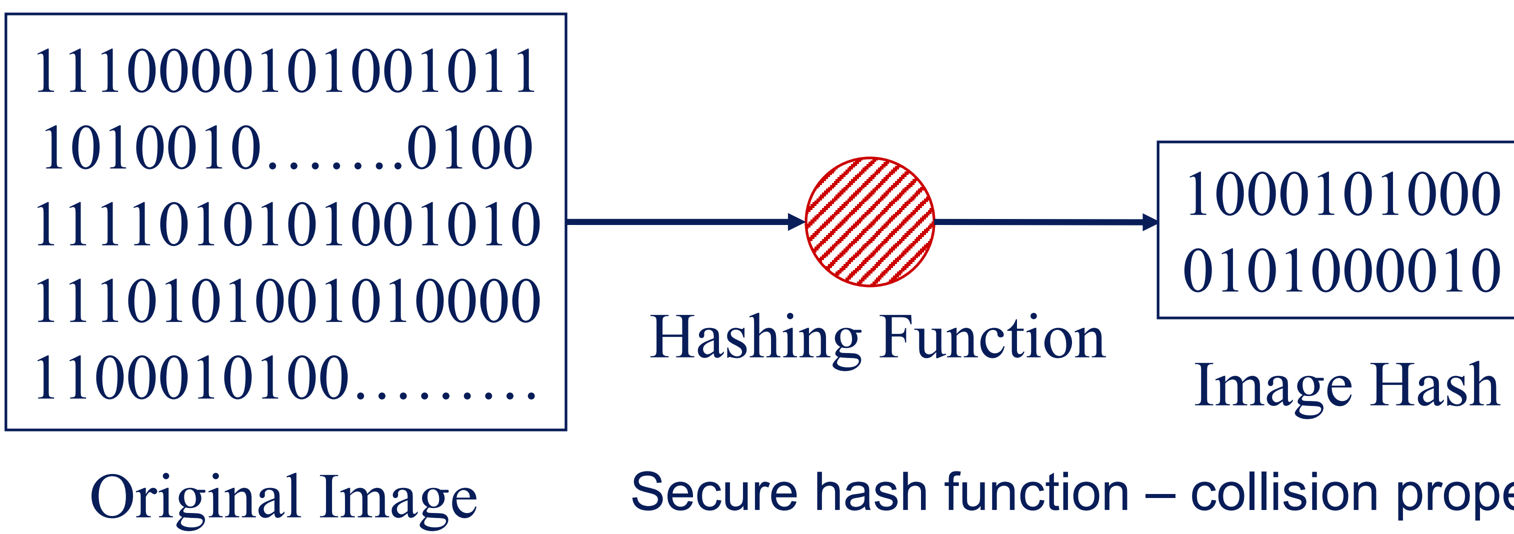
⇓

Need for multimedia (image) authentication.

- Is the problem any different from traditional authentication?
- Some new issues do exist.

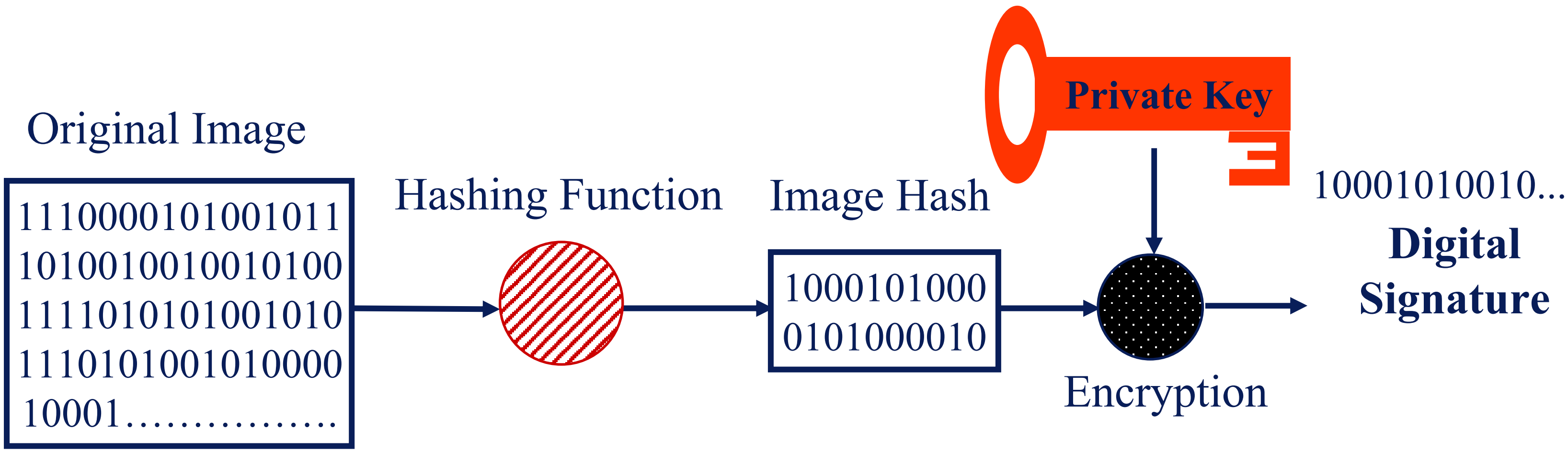
One-Way Hash Functions

- Examples of hash functions used for digital signatures are:
  - » 20-byte **secure hash algorithm** (SHA-1) that has been standardized for government applications.
  - » 16-byte **MD2**, **MD4**, or **MD5** developed by Rivest.



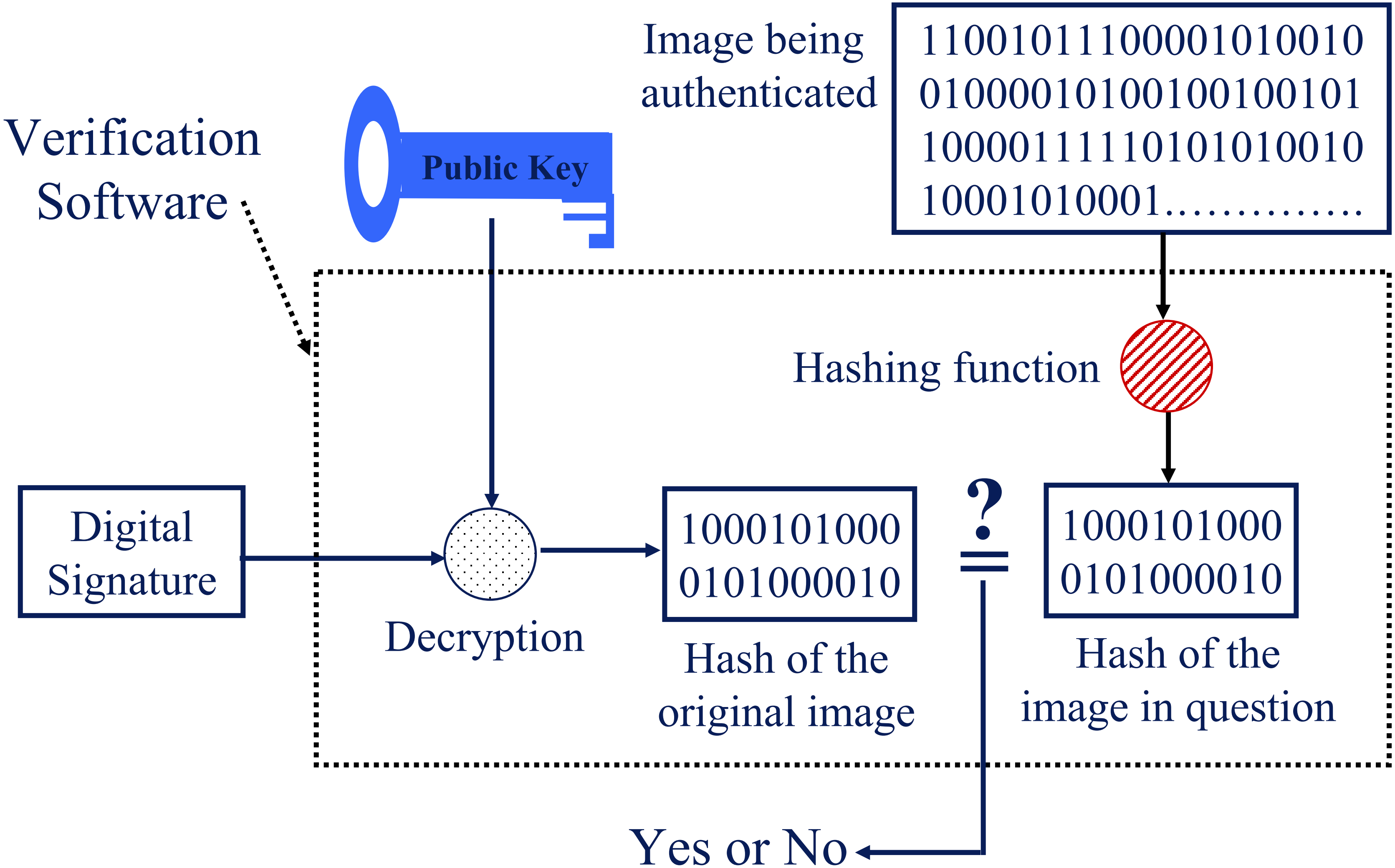
Secure hash function – collision properties

Digital Signature Generation

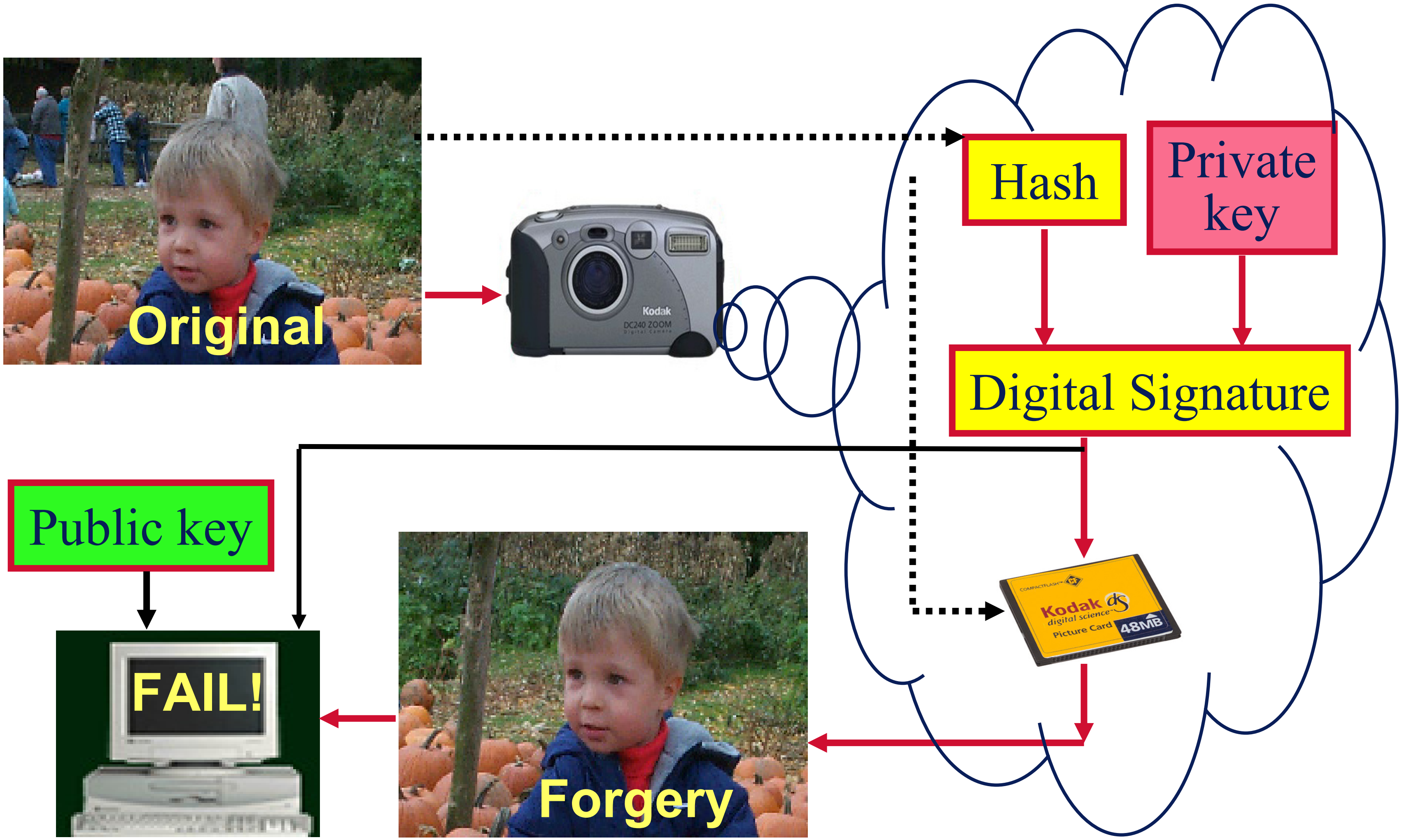


- A **digital signature** is created in two steps:
  - » A fingerprint of the image is created by using a one-way hash function;
  - » The hash value is encrypted with the private key of a public-key cryptosystem. Forging this signature without knowing the private key is computationally infeasible.

Digital Signature Verification



Digital Signature Authentication



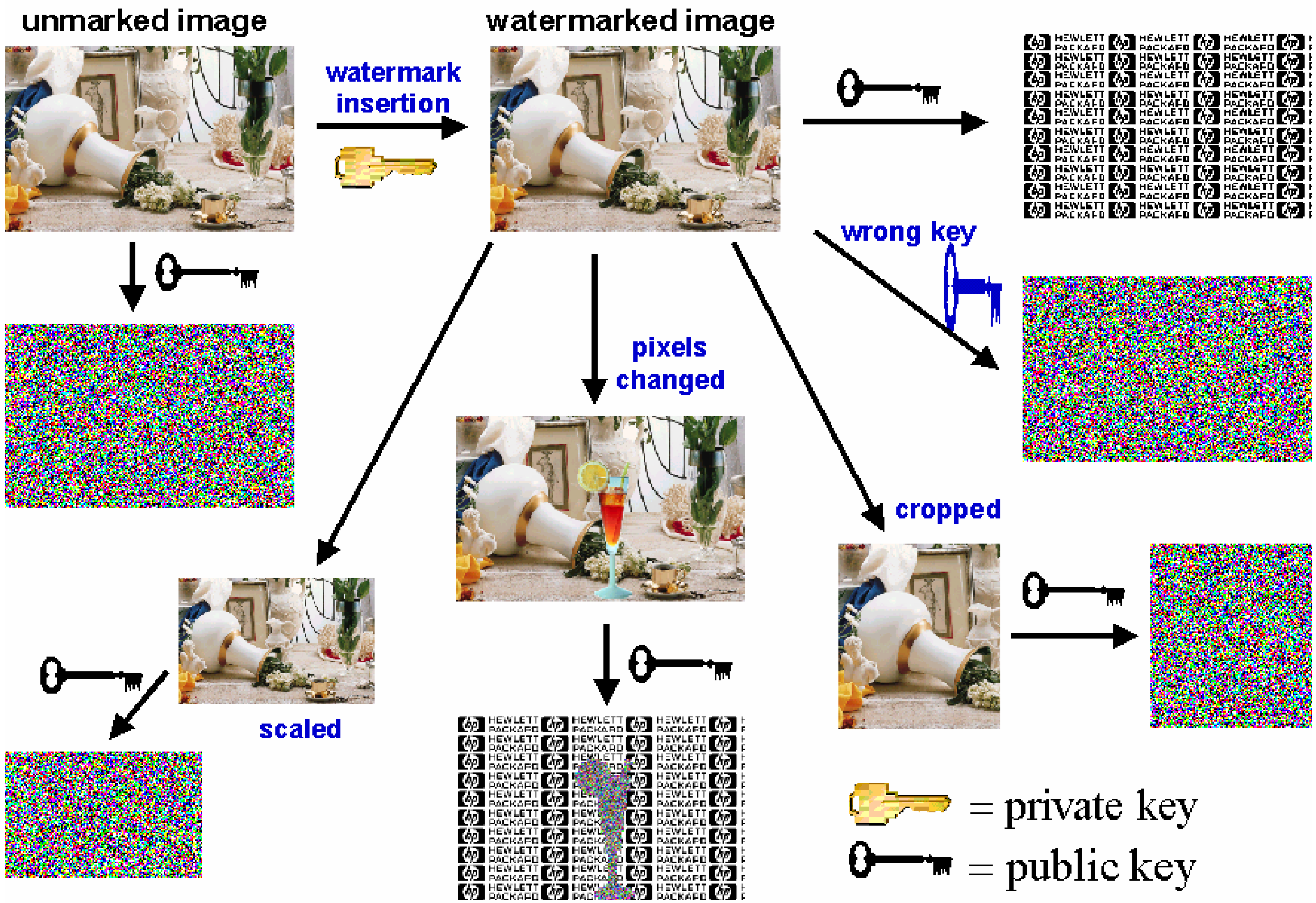
New Issues

- Authentication of "content” instead of specific representation -
  - Example - JPEG or GIF image.
- Embedding of authenticator within content
  - Survive transcoding
  - Use existing formats
- Detect local changes
  - Simple block based authentication could lead to substitution attacks
- Temporal relationship of multiple streams

Authentication Using Digital Watermarks

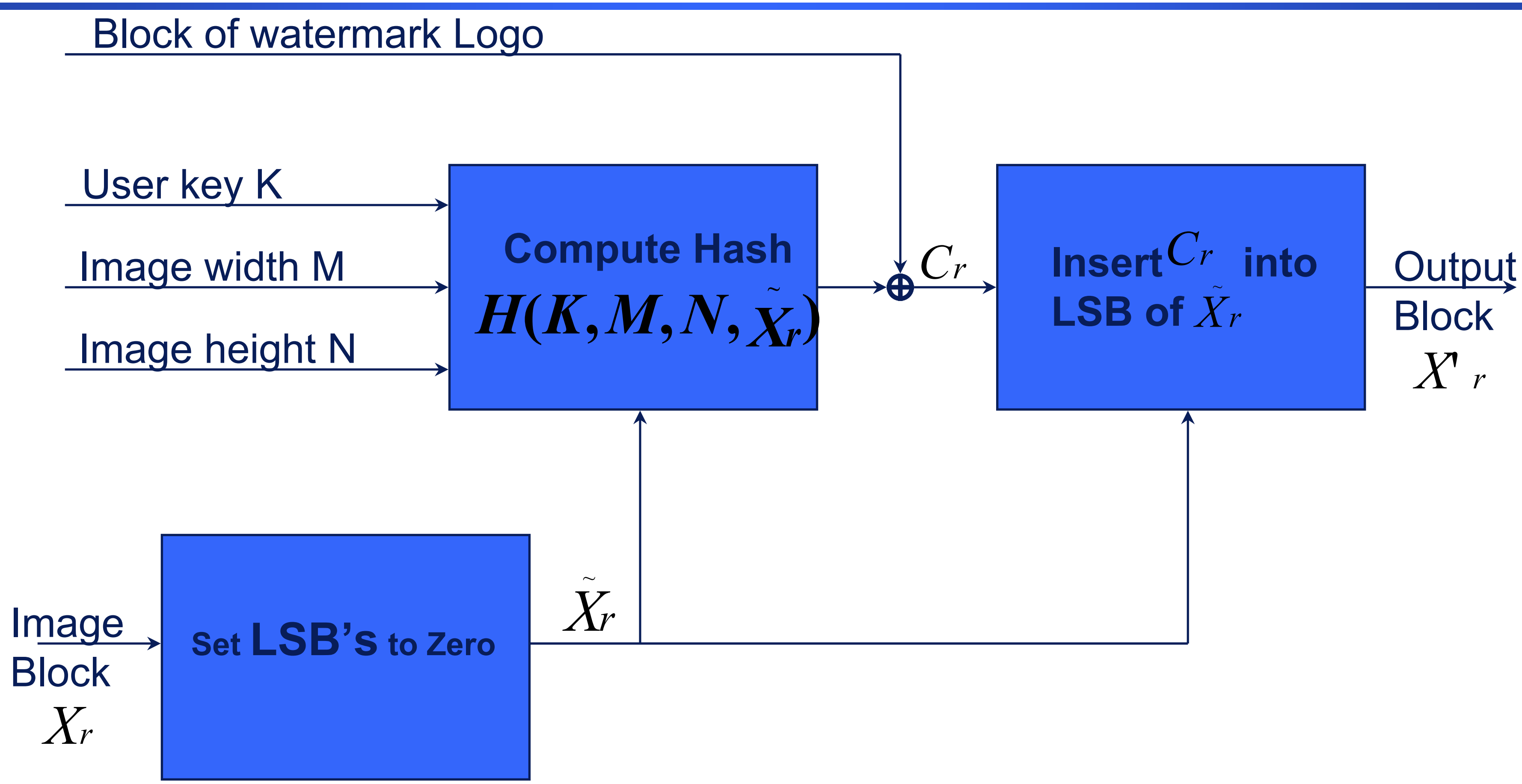
- A number of authentication techniques based on digital watermarks proposed in literature.
- A Digital watermark is a secret key dependent signal "inserted" into digital data and which can be later detected/extracted in order to make an assertion about the data.
- A digital watermark can be
  - » Fragile
  - » Robust

Fragile Watermarks



Detects and localizes any change to watermarked images.

Authentication Watermark by Wong



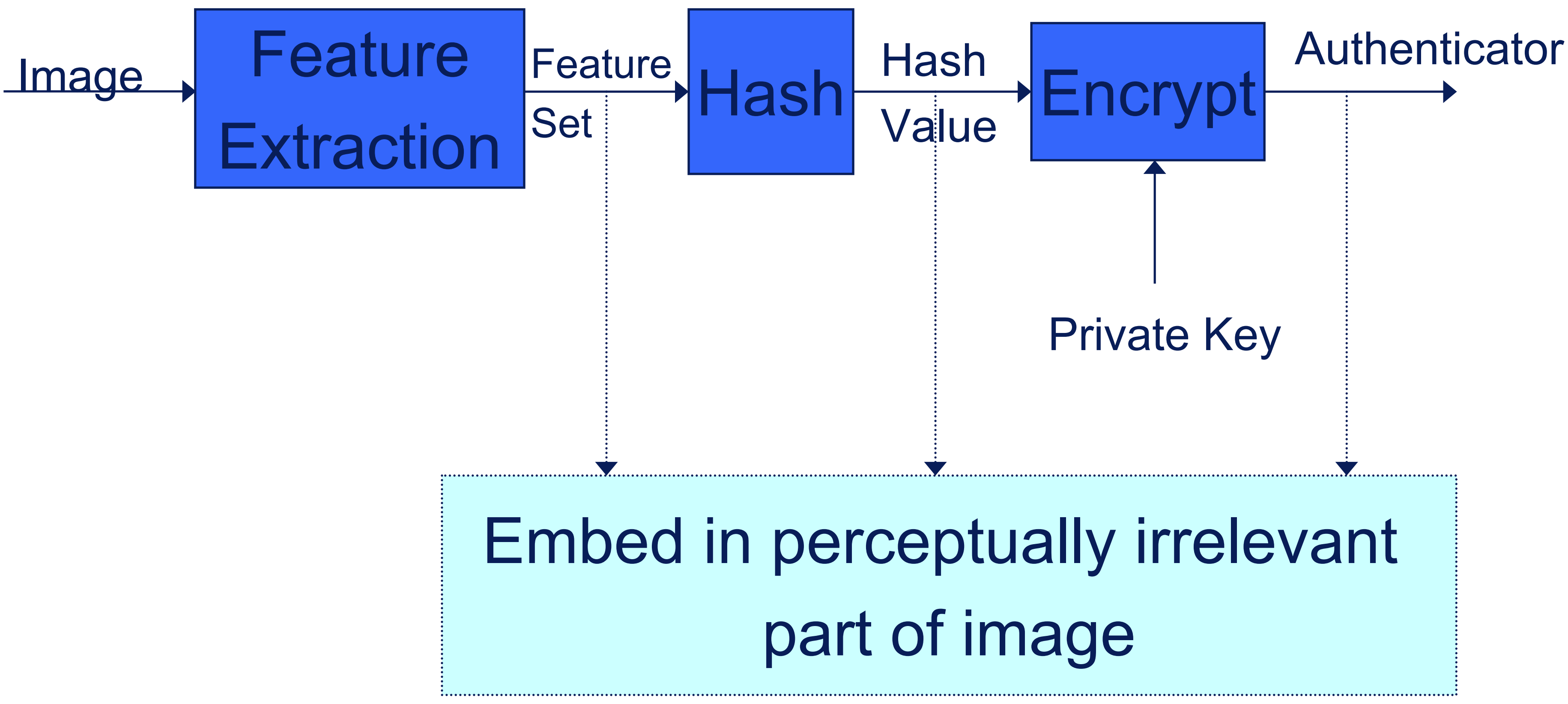
Limitations of Fragile Watermarks

- Essentially same as conventional authentication – authenticate representation and not "content".
- The differences being –
  - » Embed authenticator in content instead of tag.
  - » Treat data stream as an object to be "viewed" by an human observer.
  - » Computationally efficient?

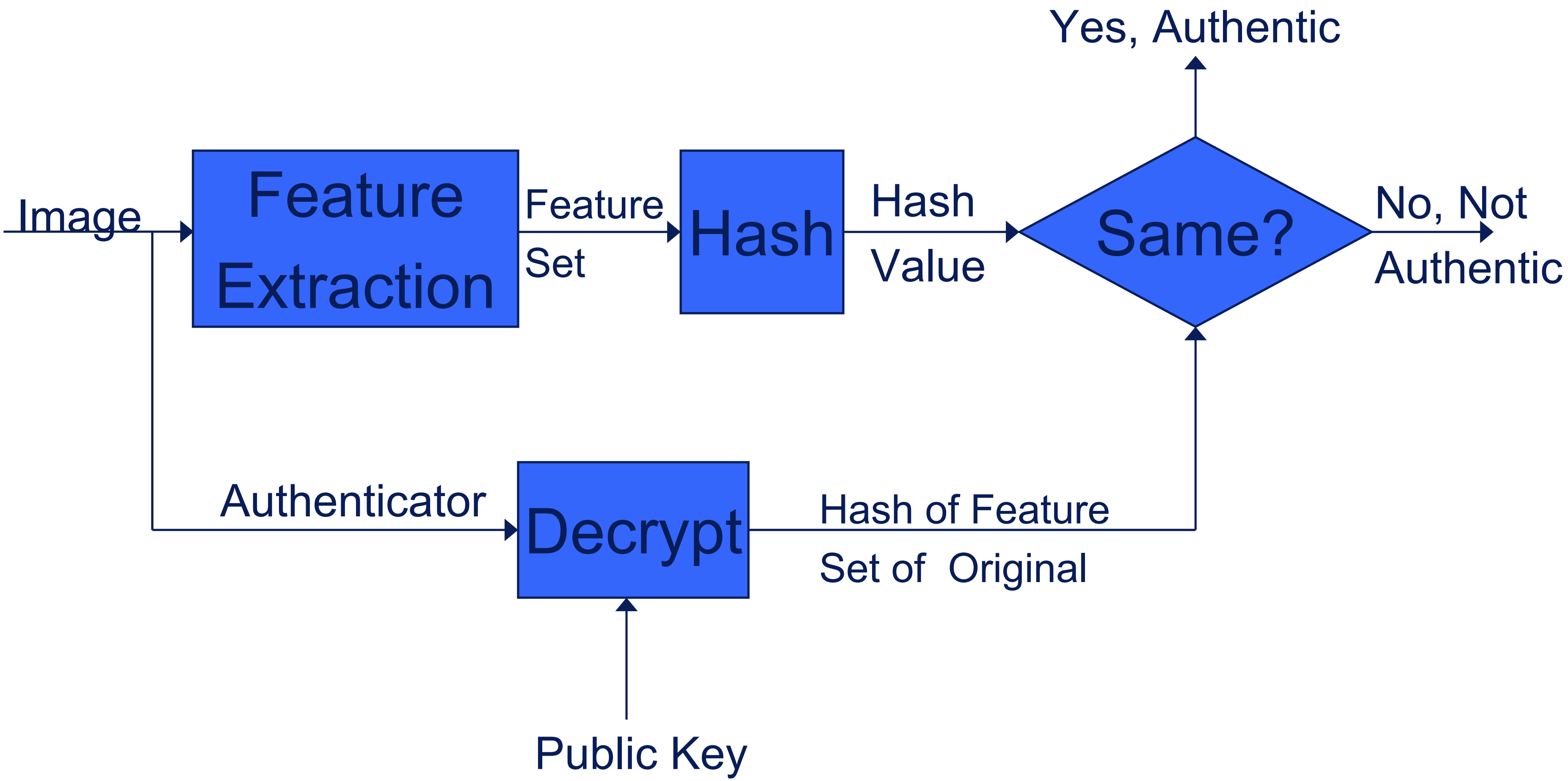
Content-based Authentication

- Number of techniques proposed -
  - Schneider and Chang (1996)
  - Bhatacharjee et. Al (1998)
  - Kundur and Hatzinakos (1998)
  - Xie and Arce (1998)
  - Fridrich (1998)
  - Fridrich (1999)
  - And many more in subsequent years …

Feature Authentication

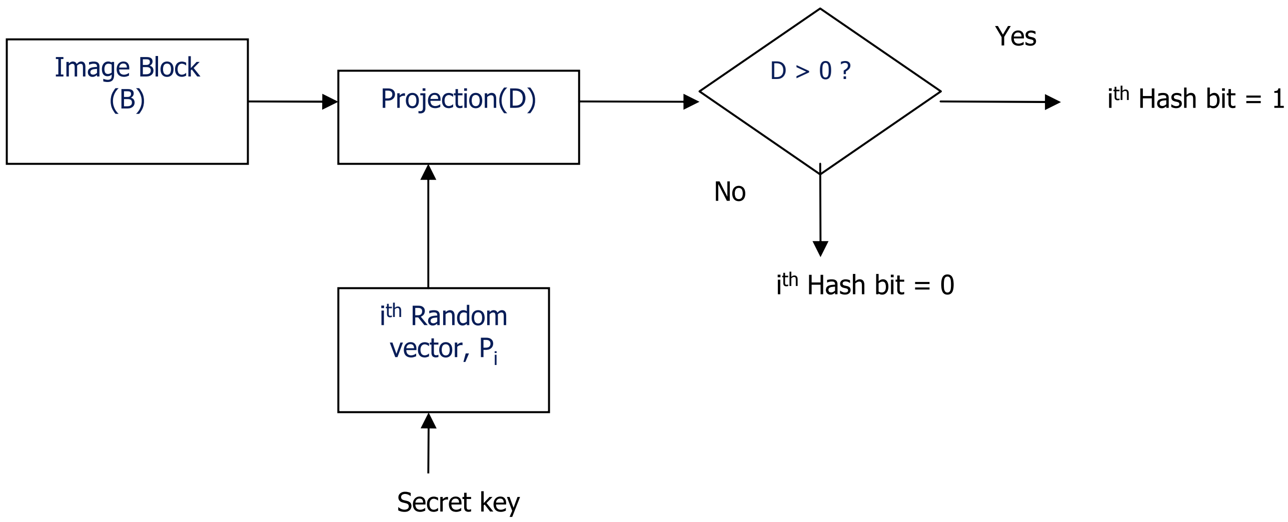


Feature Authentication (contd.)

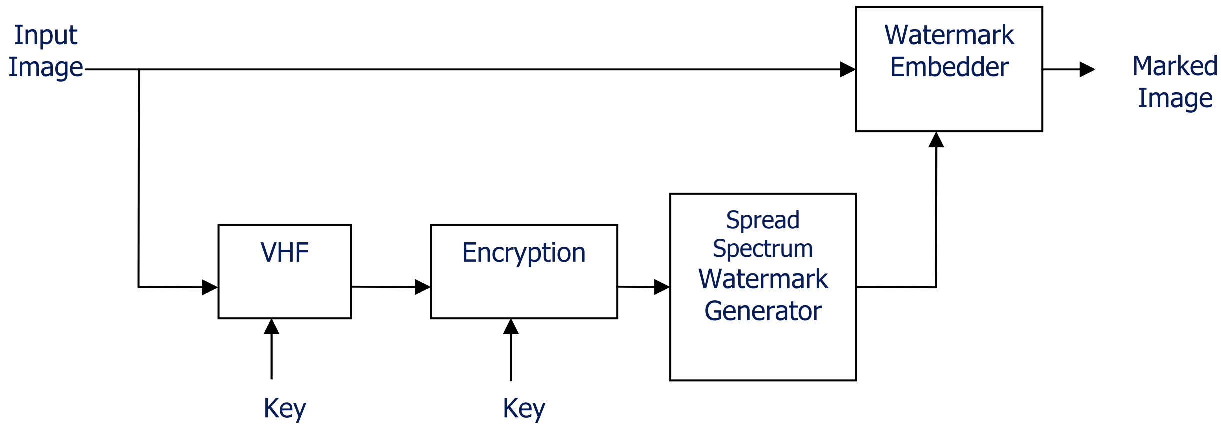


Visual Hash Generation (Fridrich 99)

- Low frequency DCT coefficients of an image cannot be changed without changing the image itself.
- Projection onto N random smooth patterns.



Overview of visual hash based image authentication system



- We have shown that collisions can be generated for the underlying hash function. (RXM 2002).

Performance of Fridrich's Algorithm

Forgery attack Probability of miss P_m		Signal processing attacks Probability of false alarm, P_f							
dB	Substitution	No attack	Smooth	Sharpen	1% salt-pepper	Histogr. equaliz.	35 dB AWGN	JPEG 70	Bit error $P_b=10^{-3}$
38	0.6%	1.1%	98.9%	20.0%	11.4%	3.1%	1.1%	6.7%	1.9%
41	1.0%	1.6%	98.3%	21.0%	19.5%	5.5%	2.5%	25.8%	2.5%

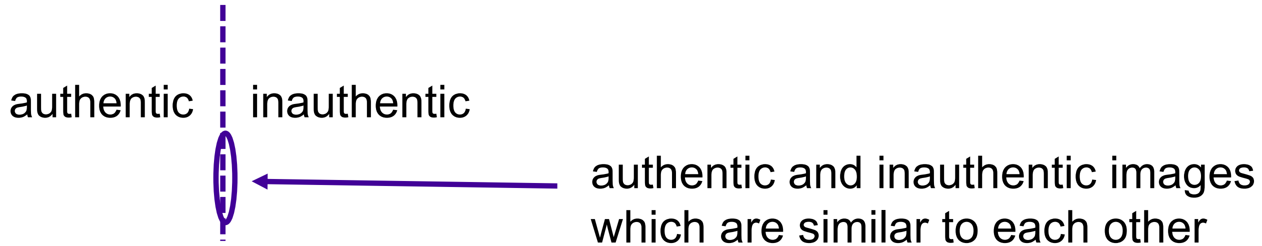
And this was the best performance from a large collection of schemes studied by Sankur et. al.!!

Limitations of feature authentication

- Difficult to identify a set of definitive features.
- Set of allowable changes has no meaningful structure – certain “small changes” may not be allowed but the same time “large” changes may be allowed in other situations.
- “Strong” features facilitate forgeries.
- “Weak” features cause too may false alarms.

Difficulties with content authentication of images

- Content is difficult to quantify.
- Malicious (benign) modifications are difficult to quantify.
- Images considered as points in continuous space means there is not a sharp boundary between authentic and inauthentic images.



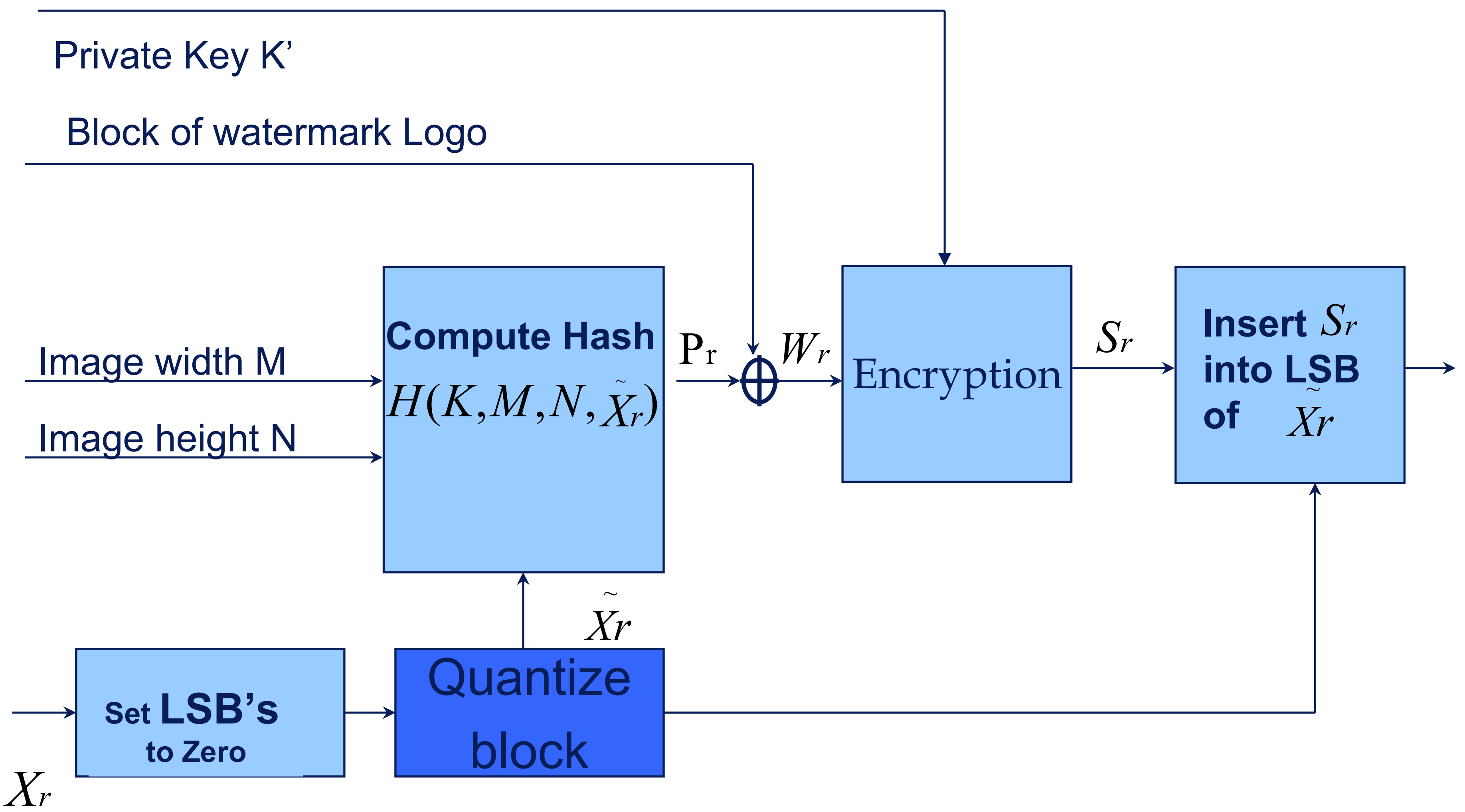
Distortion Bounded Authentication

- Memon et. al, 1999.
- Problem 1: allow flexibility in authentication to tolerate small changes
- Problem 2: to characterize and quantify the set of allowable changes
  - » Bound the errors
  - » Perceptual distortion or pixel value distortion
- Provide “guarantees” against substitution attacks.
- Approach – bounded tolerance authentication
  - » (semi-fragile)Watermarking techniques offer flexibility but most do not offer bounds

Distortion Bounded Authentication

- Quantize image blocks or features prior to computing authenticator.
- Quantization also done prior to verifying authenticity of image.
- Enables distortion guarantees – image considered authentic as long as change made does not cause quantized version to change.
- Can be used in many different ways

Distortion bounded authentication – example.

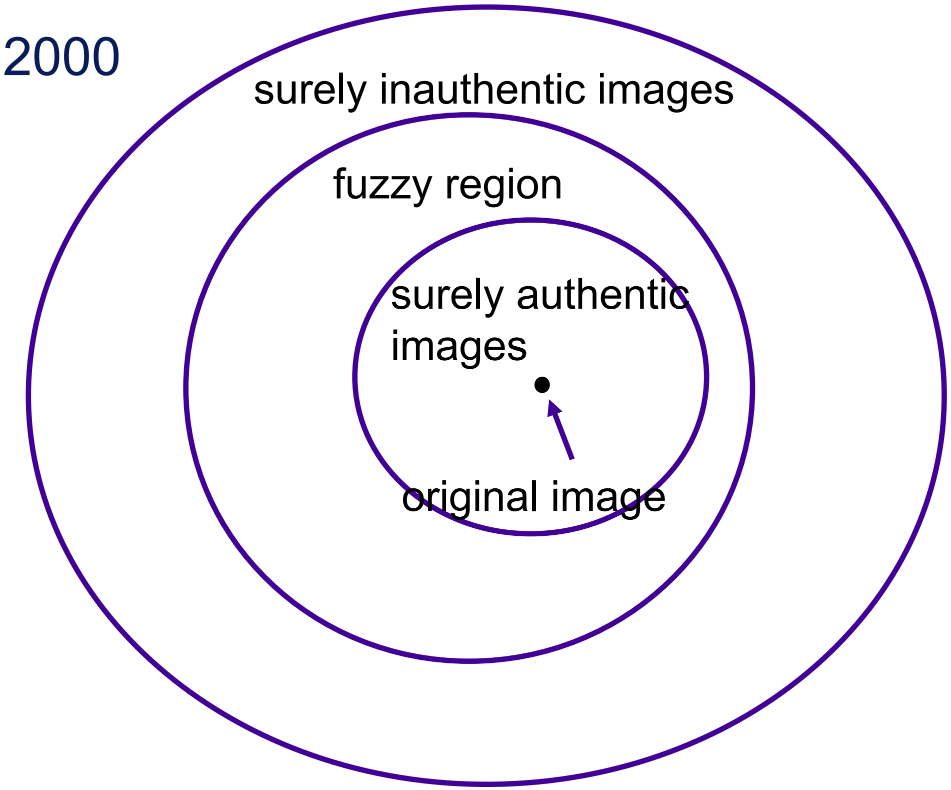


Limitations

- Distortion added to “original” image.
- Similar problems as feature authentication, though to a lesser degree.
- Significant changes may indeed be possible within specified set of allowable changes.
- How to define set of allowable changes?

A Better Approach?

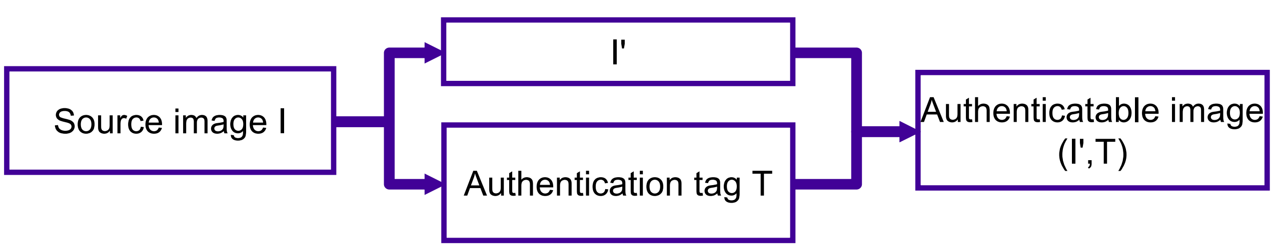
Chai Wah Wu - 2000



Fuzzy region: authenticity of image is uncertain.

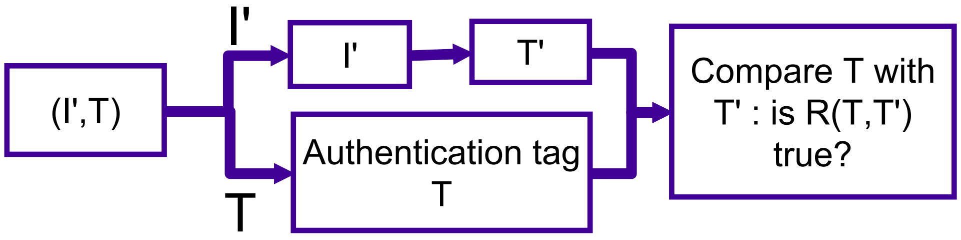
A framework of content-based image authentication

- Given a source image I, an authentication tag T is generated from I. Tag T is much smaller than I (data reduction)
- I is changed to I' in order to make it authenticatable (authenticability distortion)
- T is appended to I' resulting in an authenticatable image (I' ,T).



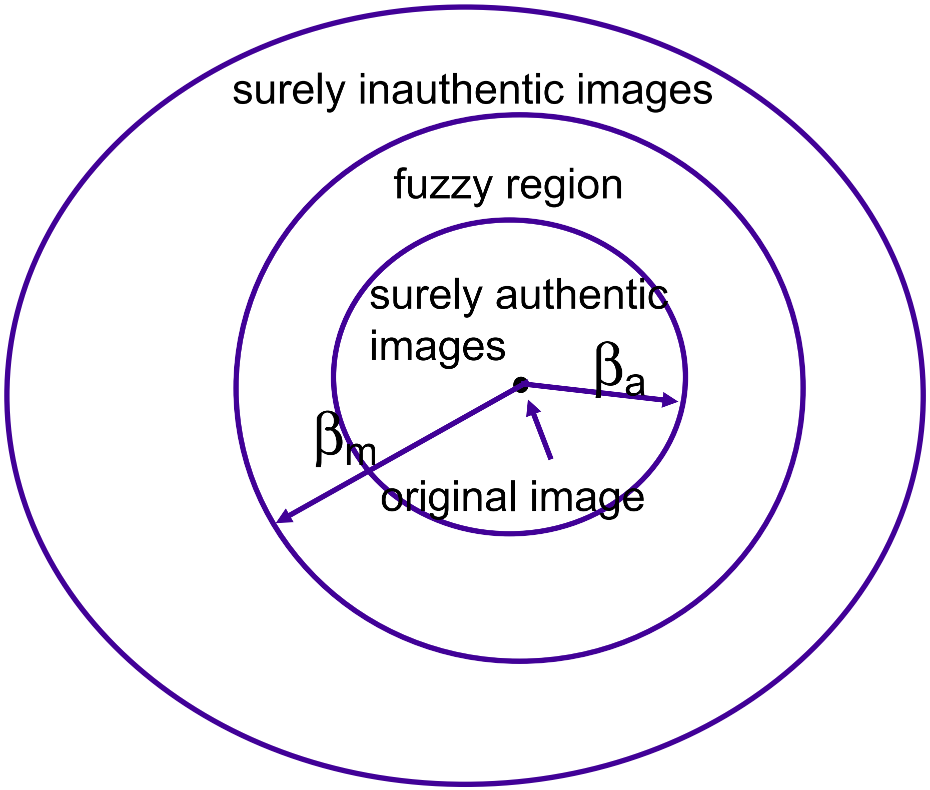
Authentication of (I' , T)

- T is extracted from (I' ,T).
- A second tag T' is computed from I'.
- T and T' are compared. If they compare favorably (R(T,T') is true), image is authentic.
- Examples of R(T,T'):
  - $d(T,T') < \varepsilon$
  - $T = T'$



Some parameters to optimize

- D, the maximum authenticability distortion.
- The size of tag T compared to the size of source image I.
- Parameters β_a and β_m: given (I',T) generated by system, if $|x| < \beta_a$, then (I'+x,T) is authentic. If $|x| > \beta_m$, then (I'+x, T) is inauthentic.
- Size of fuzzy region is determined by $\Delta\beta = \beta_m - \beta_a$.



Fuzzy region: authenticity of image is uncertain.

Extract features and check for similarity

- Tag is generated from some inherent features of image such as the location of edges.
- Given (I',T), a second tag T' is calculated from I', and image is authentic if $d(T,T') < \varepsilon$ for some metric d. Therefore similar images should generate similar tags (smoothness).
- Authenticability distortion D can be small.

Extract features and check for similarity

- Data reduction implies existence of forged images. Given a map *f* from $[0,1]^n$ to $[0,1]^m$, n >> m, there exists points x,y such that d(x,y) is close to 1, but d(*f*(x),*f*(y)) is arbitrary small.
- Smoothness in generating the tags indicate a lack of diffusion and can lead to methods to forge images, e.g. edges do not contain color information. In cryptography, preimage resistant functions generally avoid such smoothness.
- β_a and β_m difficult to determine.

Generate hash and check for equality

- Authenticability distortion is applied to source image I to generate I'.
- Tag T is generated from I' by a cryptographic hash/digital signature scheme.
- To authenticate (I',T), generate T' from I', and image is authentic if T = T'.

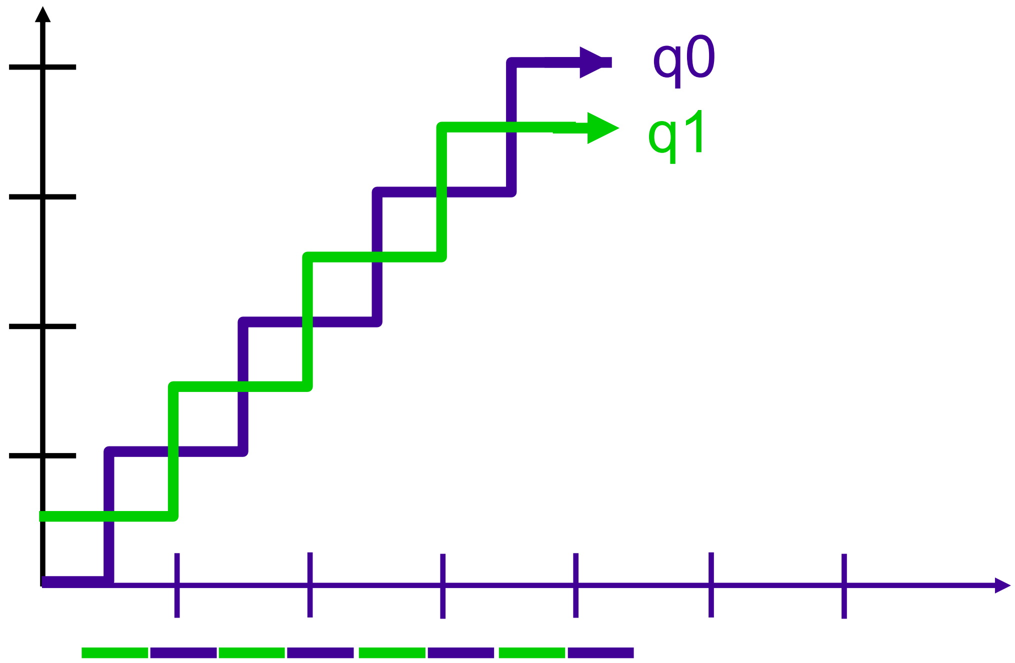
Generate hash and check for equality

- Inherit security from cryptographic hash and digital signatures.
- One can prove that $D \geq b_a$. Thus authenticability distortion is at least as large as the benign distortion that can be tolerated. In Memon et al., $D = b_a$.
- But, some applications require D=0 or $D < b_a$

Hash-based image authentication with no authenticability distortion

- Robustness to minor modifications using quantization functions.
- Utilize multiple quantization functions.
- Each point is quantized by a quantization function whose quantization boundaries are away from the point.
- The choice of quantization function is stored in an index vector.
- Quantized value is used to generate tag.

Hash-based image authentication with no authenticability distortion



Choice of q is stored in one bit of index vector. With the proper q, small changes will not affect the quantized value and the tag.

Generate authenticatable image

- Select appropriate quantization functions for each data point.
- Store choice of quantization functions in index vector.
- Quantize data point with chosen quantization function.
- Sign quantized data + index vector.
- Append lossless compressed index vector to signature and form tag.

Authentication of images

- Extract index vector and signature from tag.
- Choose quantization functions according to index vector.
- Quantize data point with chosen quantization function.
- Verify signature against quantized data + index vector.

Example

Lena RGB image in TIFF LZW format: 646KB.

Authentication tag (index vector + signature): 5.6KB.

Authenticatability distortion $D = 0$.

After JPEG compression: image is authentic.

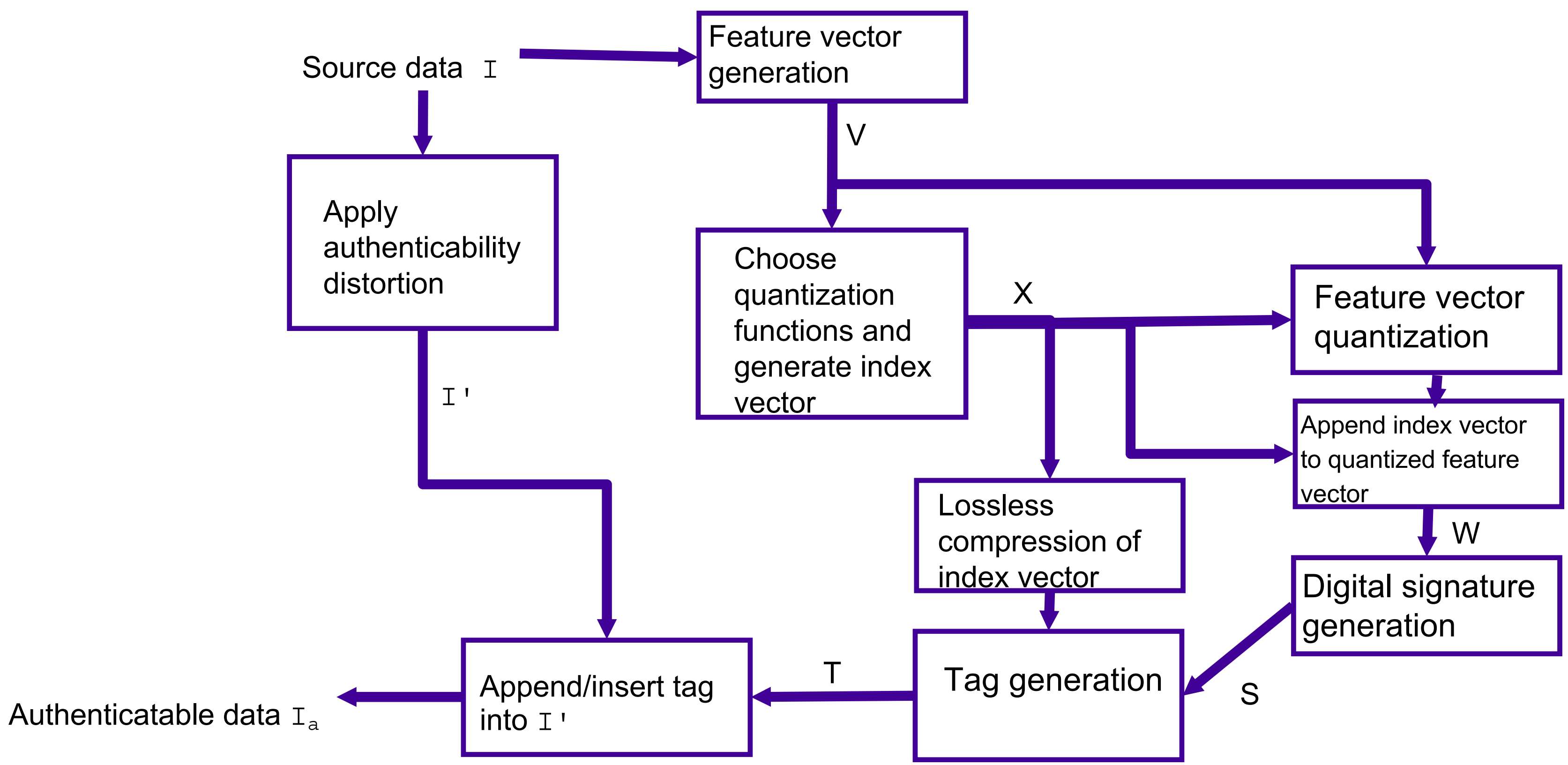
After minor brightening of image: image is authentic.

Extra strands added to hat area: image is inauthentic.

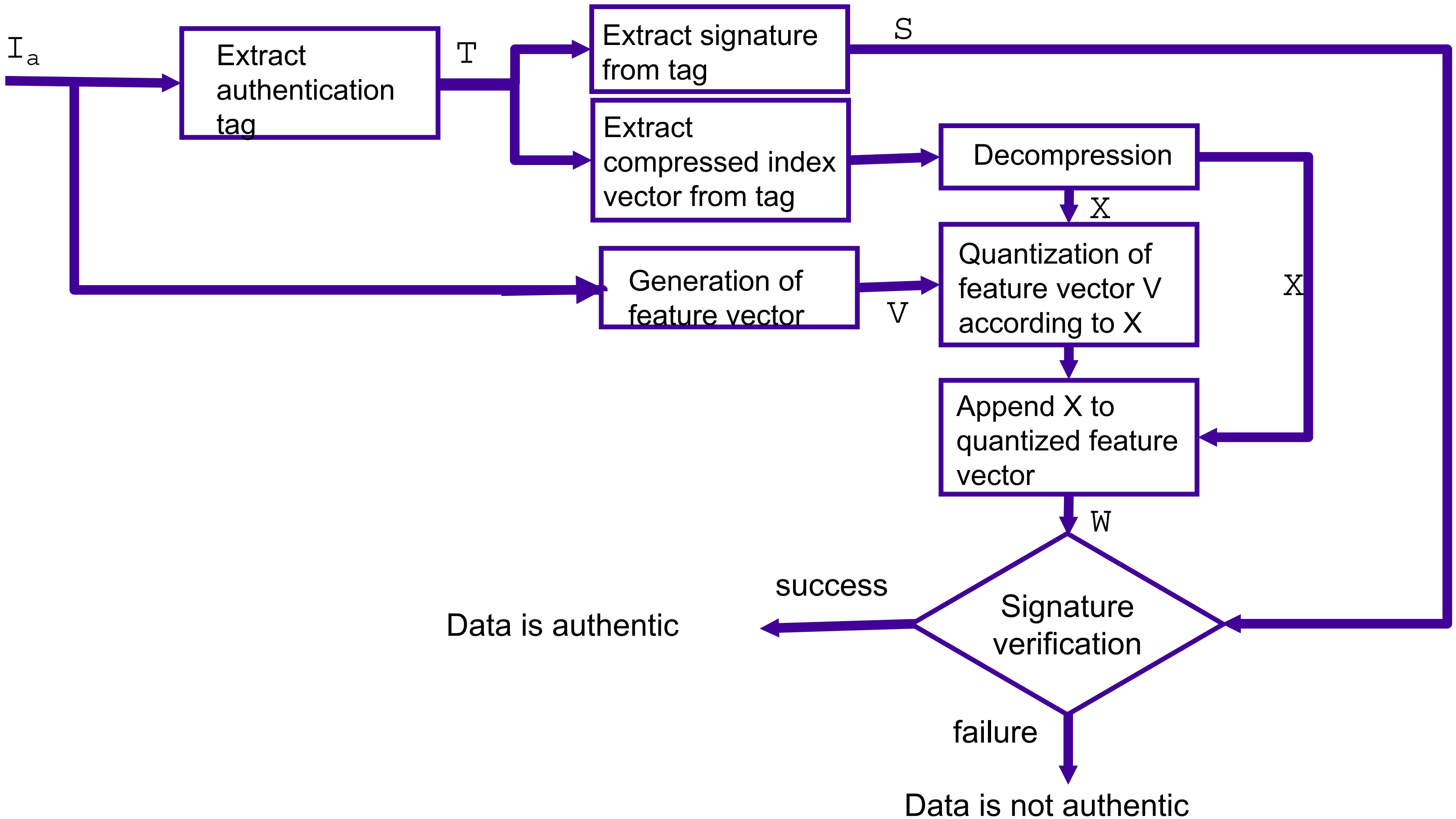
Features of the scheme

- Inherit security from cryptographic hash and digital signatures. Finding forged images which are β_m away from the original is at least as hard as breaking the underlying digital signature scheme.
- D can be smaller than β_a.
- β_a and β_m can be explicitly determined.
- Tradeoff D against size of authentication tag T.
- Tradeoff D against β_a and $\Delta\beta$.

Flowchart of procedure to generate authenticatable data



Flowchart of Authentication Procedure



Key Management

- In watermarking applications, especially authentication, it is convenient to
  - » Use same key for watermarking different images or
  - » Use same key to insert different watermarks in different images.
- We have shown on multiple occasions that above can be insecure, depending on watermarking technique and watermark inserted.

Image Dependent Key

- Attacks are possible only because same key used for seeding the pseudo-random sequence for each image.
- Can be avoided if we use different keys for different images.
- This can lead to key management problem.
- We have proposed two solutions
  - » Image dependent key - Derive key from bits extracted from image itself.
  - » Unique Salt for each image – Salt used to derive master secret. Salt stored in the clear.

Summary and Conclusions

- Multimedia content poses some new challenges for design of authentication techniques.
- We need a formal framework similar to conventional authentication.
- Bounded tolerance – trading off flexibility and quantifiable errors (comfort zone) is a good approach.
- Many schemes become vulnerable with same key used to mark multiple objects. Image dependent keys or salting offer good mechanisms to prevent such attacks.