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Encounters in Vanuatu: process and interactions in visual arts

Catherine Kay
University of Wollongong

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Recommended Citation

Kay, Catherine, Encounters in Vanuatu: processes and interactions in visual arts, MCA thesis, Faculty of Creative Arts, University of Wollongong, 2009. <http://ro.uow.edu.au/theses/4055>

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Building Babel: Freeing multimedia processing and delivery from hard-coded formats

A thesis submitted in fulfilment of the
requirements for the award of the degree

Doctor of Philosophy

from

UNIVERSITY OF WOLLONGONG

by

Joseph Alfred Ian Thomas-Kerr
Bachelor of Engineering (Honours Class I)
University of Wollongong, 2003

SCHOOL OF ELECTRICAL, COMPUTER
AND TELECOMMUNICATIONS ENGINEERING
2009

Abstract

The amount of multimedia content available via the Internet, and the number of formats in which it is encoded, stored and delivered continues to grow rapidly. So too the number and diversity of the devices and software applications which produce, process and consume such content. This constantly changing landscape presents an increasing challenge to interoperability, since more and more software and hardware must be upgraded as new formats are developed. However, many of the operations performed on multimedia content are similar across coding formats. In recognising this, this thesis proposes several approaches to *format-independent* media processing, with an emphasis on content delivery. This considerably simplifies interoperability, since support for a new content format may be provided by disseminating a data file, rather than requiring application and device providers to extend and modify their software and hardware.

A fundamental requirement for format-independence is the ability to describe the structure of any given format in a way that exposes how it may be fragmented for delivery or processing, and how other data important to the processing (for instance temporal or scalability parameters) can be extracted from the binary data. Several

meta-syntax languages are evaluated that (to greater or lesser degree) perform this function. Of these, the most suitable for general use in format-independent processors is found to be MPEG-21's Bitstream Syntax Description Language (BSDL). Its general suitability notwithstanding, BSDL exhibits several critical flaws when used to describe and process modern content formats. In response, this thesis proposes several new features for the language which significantly reduce processing complexity, and provide extensibility for complex data types. These features are implemented and validated using bitstreams of real-world length, which enable a linear response of approximately 10 times the speed of playback (on the particular test machine used), for videos up to one hour in duration.

Digital media increasingly encompasses a wide range of metadata, as well as collections of related content (a DVD and its "special features", for instance). Several recent standards address generic virtual containers for such rich content. While these standards—which include MPEG-21 and TVAnytime—provide numerous tools for interacting with rich media objects, they do not provide a framework for streaming or delivery of such data. This thesis presents the Bitstream Binding Language (BBL), a format-independent tool that describes how multimedia content and metadata may be bound into delivery formats. Using a BBL description, a generic processor can map rich content (an MPEG-21 Digital Item, for example) into a streaming or static delivery format. BBL provides a universal syntax for fragmentation and packetisation of both XML and binary data, and allows new content and metadata formats to be delivered without requiring the addition of new software to the delivery infras-

tructure. The BBL framework is validated and tested against a number of application scenarios including a format-independent streaming server, generic metadata syntax translation, virtual container assembly, and a format-independent hinter.

Finally, it is observed that much of the semantic metadata that is generated to describe multimedia content could also be used to improve the decisions that must be made in order to transmit it effectively. Indeed, methods have been proposed for using *specific* semantic concepts in the delivery process. However, until now, no high-level system has been proposed that is able to take arbitrary semantic metadata, and utilise it in the multimedia delivery decision-making process. This thesis proposes such a system. It combines the aforementioned semantic concepts with other existing work in Rate-Distortion Optimisation for multimedia delivery, scalable content formats, and syntax description, and then develops a generalised framework to permit an arbitrary range of semantic metadata and optimisation techniques to be utilised. This objective is accomplished by utilising *schema* languages to describe the details of any given content or metadata, so that declarative mapping rules can be specified for translating from format-specific data points to format-independent concepts that are directly used by the framework. This translation can then be performed using software or hardware that knows nothing about the specific format it is processing.

This thesis describes a particular embodiment of the semantic-aware multimedia delivery system which was implemented in order to verify its key assertions. It presents the results of subjective testing that was performed on several short news clips encoded using H.264/SVC scalable video coding, and Scalable-To-Lossless (SLS) au-

dio coding. Each clip was adapted to four target bitrates, using both of two methods:

- (a) using the semantic-aware system to devote a greater proportion of the available bandwidth to that part of the content (audio or video) that was conveying more of the semantics at any given time; and
- (b) at a constant bit-rate with the same average rate as clip (a).

Test participants were shown each pair of clips (a and b) in a random order and were asked to evaluate which was more successful at conveying the meaning of the story. The result of this subjective testing was a 72% preference for those clips which had been adapted so as to devote more bandwidth to the semantically-important parts of the content.

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Statement of Originality

This is to certify that the work described in this thesis is entirely my own, except where due reference is made in the text.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed

A handwritten signature in dark ink, appearing to read 'J. A. I. Thomas-Kerr', written in a cursive style.

Joseph Alfred Ian Thomas-Kerr

12th of May, 2009

Acknowledgments

I am indebted to many people, without whom this thesis would not be. To them I offer my heartfelt gratitude.

Firstly, to my Creator, the source of all creativity and inspiration, and my closest companion.

To my wife, Michelle, my lover, best friend, confidant, and editor.

To my supervisors, Ian Burnett and Christian Ritz, whose guidance and reassurance were indispensable.

Campbell Thomas, my father-in-law, for the affirmation which helped me persevere through trying circumstances.

And to Molly and Edward, heartbeats at my feet, never leaving, always believing.

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List of Abbreviations

3GPP	3rd Generation Partnership Project
AAC	Advanced Audio Coding
ADIF	Audio Data Interchange Format
ANSI	American National Standards Institute
API	Application Programming Interface
APIC	Associated Picture
ASIC	Application-Specific Integrated Circuit
ASN.1	Abstract Syntax Notation 1
AU	Access Unit
AVC	Advanced Video Coding
AVI	Audio-Video Interchange
BBL	Bitstream Binding Language
BFlavor	BSDL Flavor
BintoBSD	Binary to BSD
BPath	Binary Path Language
BS Schema	Bitstream Syntax Schema
BSD	Bitstream Syntax Description

BSDL	Bitstream Syntax Description Language
BSDtoBin	BSD to Binary
CAL	CAL Actor Language
CALML	CAL XML Syntax
CDATA	Character Data
CGS	Coarse-Grained Scalability
CMML	Continuous Media Markup Language
CSDF	Cyclo-Static Data Flow
CSP	Communicating Sequential Processes
DAB	Digital Audio Broadcasting
DAML	DARPA Agent Markup Language
DARPA	Defense Advanced Research Projects Agency
DCT	Discrete Cosine Transform
DDL	Decoder Description Language
DI	Digital Item
DIDL	Digital Item Description Language
DMB	Digital Multimedia Broadcasting
DOM	Document Object Model
DRM	Digital Rights Management
DVB	Digital Video Broadcasting
DVD	Digital Versatile Disc
EBNF	Enhanced Backus Naur Form

ECMA	European Computer Manufacturers Association
EXIF	EXchangeable Image File format
FGS	Fine-Granular Scalability
FIFO	First-In First-Out
FLAVOR	Formal Language for Audio Visual Object Representation
FPGA	Field-Programmable Gate Array
FSM	Finite State Machine
GIF	Graphics Interchange Format
GNU	GNU's Not Unix
GZIP	GNU Zip
HTML	HyperText Markup Language
ID	Identification
ID3	IDentify mp3
IDCT	Inverse Discrete Cosine Transform
IETF	Internet Engineering Task Force
ISO	International Standards Organisation
ITU	International Telecommunication Union
JPEG	Joint Photographic Experts Group
JVM	Java Virtual Machine
LQP	Quantisation parameter from the SVC reference software
MAF	Multimedia Application Format
MB	Macroblock

MDR-V500	A model of stereo headphones made by Sony
MP3	MPEG Layer 3 audio format
MPEG	Motion Picture Experts Group
MTU	Maximum Transmission Unit
NAL	Network Abstraction Layer
NALU	NAL Unit
NPT	Normal Playback Time
OIL	Ontology Inference Layer
OWL	Web Ontology Language
PCM	Pulse-Coded Modulation
PES	Packetised Elementary Stream
PPS	Picture Parameter Set
QCIF	Quarter-Common Interchange Format
QName	Qualified Name
QT	QuickTime
QTFF	QuickTime file format
QVGA	Quarter VGA
RDD	Rights Data Dictionary
RDF	Resource Description Framework
RDFS	RDF Schema
RDO	Rate-Distortion Optimisation
RGB	Red-Green-Blue

RFC	Request for Comment
RMC	Reconfigurable Media Coding
RQP	Quantisation parameter from the SVC reference software
RTP	Real-time Transport Protocol
SAX	Simple API for XML
SBS	Special Broadcasting Service
SCR	System Clock Reference
SD	Semantic Distortion
SDF	Synchronous Data Flow
SDP	Session Description Protocol
SI	Spatial Information
SLOC	Source Lines of Code
SLS	Scalable-to-Lossless coding
SMPTE	Society of Motion-Picture and Television Engineers
SNR	Signal-to-Noise Ratio
SPS	Sequence Parameter Set
SSRC	Synchronization Source
SVC	Scalable Video Coding
SWQL	Semantic Web Query Language
SWRL	Semantic Web Rule Language
TI	Temporal Information
TIFF	Tagged Image File Format

TS	Transport Stream
UMA	Universal Multimedia Access
URI	Universal Resource Identifier
URL	Universal Resource Locator
VC.1	Video Codec 1
VGA	Video Graphics Array
VHDL	VHSIC Hardware Description Language
VHSIC	Very High-Speed Integrated Circuit
VLC	Variable-Length Coding
VOL	Video Object Layer
VOP	Video Object Plane
WBXML	WAP Binary XML
WAP	Wireless Access Protocol
XFlavor	XML FLAVOR
XML	eXtensible Markup Language
XPath	XML Path Language
XQuery	XML Query Language
XSD	XML Schema Description
XSL	XML Stylesheet Language
XSLT	XSL Transformations
XStream	XML Stream
YCrCb	Luminance-Chrominance colour space