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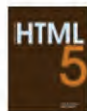
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Product Description

HTML5 is here, and with it, web applications take on a power, ease, scalability, and responsiveness like never before. In this book, developers will learn how to use the latest cutting-edge HTML5 web technology—available in the most recent versions of modern browsers—to build web applications with unparalleled functionality, speed, and responsiveness.

- Explains how you can create real-time HTML5 applications that tap the full potential of modern browsers
- Provides practical, real-world examples of HTML5 features in action
- Shows which HTML5 features are supported in current browsers
- Covers all the new HTML5 APIs to get you up to speed quickly with HTML5

What you'll learn

- How the HTML5 specification has evolved
- How to develop cutting-edge web applications using new HTML5 features like WebSockets, Geolocation, Web Storage, Canvas, and Audio and Video.
- Which features are available in browsers today

Who is this book for?

This book is for web designers and developers who want to use the latest cutting-edge technology available in current browsers; developers who want to create dynamic, HTML5 web applications; and developers who want to know which HTML5 features are supported in current browsers.

About the Author

Peter Lubbers is the Director of Documentation and Training at Kaazing Corporation and the co-founder of the San Francisco HTML5 User Group. Peter also teaches HTML5 training courses all over the world. Prior to joining Kaazing, Peter worked as an information architect at Oracle, where he wrote many books, including the award-winning Oracle Application Server Portal Configuration Guide. At Oracle, Peter also developed documentation automation solutions and two of his inventions are patented. A native of the Netherlands, Peter served as a Special Forces commando in the Royal Dutch Green Berets. Peter lives on the edge of the Tahoe National Forest and in his spare time, he loves to run ultra marathons in the Sierra Nevada foothills and around Lake Tahoe (preferably in one go!).

Brian Albers is the VP of development at Kaazing. Brian has over 13 years of experience in the field of User Interface technologies. Prior to joining Kaazing, Brian worked as Senior Development Manager at Oracle, where he led the planning and designing of the next generation of Oracle's UI technology—an effort publicly known as ADF Faces.

During his 10 year tenure at Oracle, Brian worked primarily on mixing cutting-edge technology with large enterprise demands (internationalization, accessibility, scalability). He proposed the open source donation of ADF Faces, which ultimately became the Apache MyFaces Trinidad project. Brian also led a cross-team effort to develop a DHTML rich client and a mobile client presentation layer for Oracle's Project Fusion.

Brian received a BS degree in Computer Science from the University of Texas, Austin, and a BA degree in Plan II Honors from the University of Texas, Austin.

Ric Smith is director of Oracle's Fusion Middleware E20 Architect Team. Formerly, he led business and product strategy at Kaazing. Ric has also held various roles in product management, consulting, and software engineering. In addition, Ric is a frequent speaker at international events and has written articles featured in leading industry publications such as Java Developer's Journal and AJAX World Magazine.

Frank Salim is a polyglot programmer with a keen interest in making life easier for his fellow coders. Frank leads WebSocket development at Kaazing. He is an open source advocate and a committer in several open source projects.

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Peter Lubbers, Brian Albers, Ric Smith, and Frank Salim put together an excellent resource for powerful yet practical HTML5 code that can be used NOW. The book refutes the myth that HTML5 will not be usable until 2022 by going on and showing you how to use it today! By leveraging API's that have common browser support the effort is not purely academic. Although the code is targeted for a more advanced audience, an adept user will be able to glean plenty of information from the examples. The book answered many questions I had about the emerging HTML5 standards, and gave me some new techniques to implement. I recommend this book for anyone experienced with HTML who wants to start using HTML5 now.

1 of 14 people found the following review helpful:

Good and bad, September 11, 2010

By **devlim "Coder . Designer"** (Malaysia) - [See all my reviews](#)

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Good because it teaches what the title writes, bad because it didn't use proper examples. Like the chapter creating HTML5 Offline Web Applications, where it uses the HTML5 geolocation, localstorage, and offline API. It didn't give us the server-side code that processes the data, and the geolocation URL that this book uses was [...], god, example.net? pretty funny.

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Guinard, D. (2011). *A web of things application architecture: Integrating the real-world into the web* (Doctoral dissertation, ETH Zurich).

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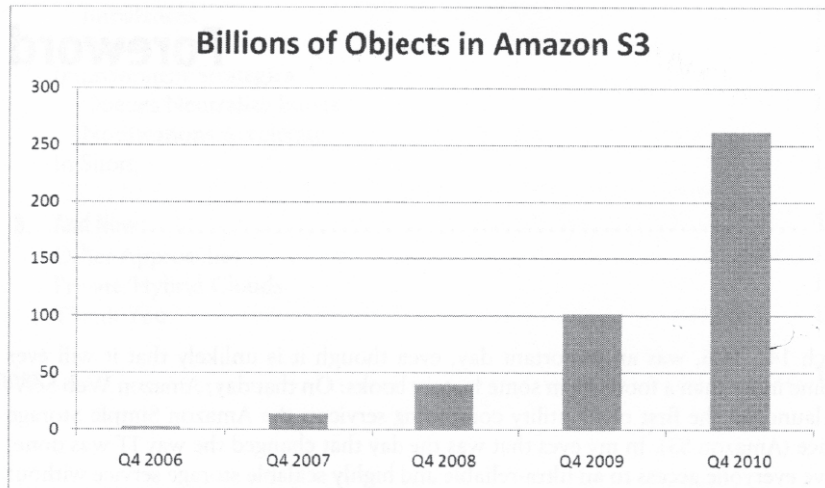
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Following Amazon S3, we launched Amazon Simple Queue Service (Amazon SQS), and then Amazon Elastic Compute Cloud (Amazon EC2) just a few months later. These services demonstrated the power of what we have come to call Cloud Computing: access to highly reliable and scalable infrastructure with a utility payment model that drives innovation and dramatically shortens time to market for new products. Many CIOs have told me that while their first motivation to start using AWS was driven by the attractive financial model, the main reason for staying with AWS is that it has made their IT departments agile and allowed them to become enablers of innovation within their organization.

The AWS platform of technology infrastructure services and features has grown rapidly since that day in March 2006, and we continue to keep that same quick pace of innovation and relentless customer focus today.

Although AWS, as well as its ecosystem, has launched many tools that make using the services really simple, at its core it is still a fully programmable service with incredible power, served through an API. Jurg and Flavia have done a great job in this book of building a practical guide for how to build real systems using AWS. Their writing is based on real experiences using each and every one of the AWS services, and their advice is rooted in building foundations upon which applications on the AWS platform can scale and remain reliable. I first came in contact with them when they were building Decaf, an Android application used to control your AWS resources from your mobile device. Since then, I have seen them help countless customers move onto the AWS platform, and also help existing customers scale better and become more reliable while taking advantage of the AWS elasticity to drive costs down. Their strong customer focus makes them great AWS partners.

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AWS will continue to innovate on behalf of our customers, and there are still very exciting things to come.

—Werner Vogels
VP & CTO at Amazon.com

Preface

Thank you for picking up a copy of this book. Amazon Web Services (AWS) has amazed everyone: Amazon has made lots of friends, and all its “enemies” are too busy admiring AWS to do much fighting back. At the moment, there is no comparable public Infrastructure as a Service (IaaS); AWS offers the services at a scale that has not been seen before. We wrote this book so you can get the most out of AWS’ services. If you come from conventional hardware infrastructures, once you are on AWS, you won’t want to go back.

AWS is not easy; it combines skills of several different (established) crafts. It is different from traditional systems administration, and it’s not just developing a piece of software. If you have practiced one or both of these skills, all you need is to be inquisitive and open to learning.

Our background is in software engineering. We are computer scientists with extensive software engineering experience in all sorts of different fields and organizations. But the cloud in general and AWS in particular caught our interest some years ago. We got serious about this by building Decaf, an Android smartphone application that manages Amazon EC2 (Elastic Compute Cloud) accounts. We were finalists in the Android Developer Challenge in 2009. We will use Decaf to illustrate various AWS services and techniques throughout this book.

Around the same time, in early 2010, we decided we wanted to build applications on AWS. We founded 9Apps and set out to find a select group of partners who shared our development interests. Our expertise is AWS, and our responsibility is to keep it running at all times. We design, build, and operate these infrastructures.

Much of our experience comes from working with these teams and building these applications, and we will use several of them as examples throughout the book. Here is a short introduction to the companies whose applications we will use:

Directness

Directness helps customers connect brands to businesses. With a set of tools for making surveys and collecting, interpreting, and presenting consumers’ feedback, this application is very successful in its approach and works with a number of international firms. The problem is scaling the collection of customer responses,

transforming it into usable information, and presenting it to the client. Directness can only grow if we solve this problem.

Kulitzer

Kulitzer is a web application that allows users to organize creative contests. Users can invite participants to enter the contest, an audience to watch, and a jury to pick a winner. Technically, you can consider Kulitzer a classical consumer web app.

Layar

Layar is an augmented reality (AR) smartphone browser that is amazing everyone. This application enriches the user's view of the world by overlapping different objects or information in the camera view, relevant to the location. For example, users can see what people have been tweeting near them, the houses that are for sale in the neighborhood, or tourist attractions near where they are walking.

The Layar application continues to win prize after prize, and is featured in many technical and mainstream publications. Layar started using Google App Engine for its servers, but for several reasons has since moved to AWS.

Marvia

Ever needed to create some "print ready" PDFs? It's not an easy task. You probably needed desktop publishing professionals and the help of a marketing agency, all for a significant price tag. Marvia is an application that can dramatically reduce the effort and cost involved in PDF creation. It allows you to create reusable templates with a drag-and-drop web application. Or you can integrate your own system with Marvia's API to automate the generation of leaflets and other material.

Publitas

Publitas does the opposite of what Marvia does, in a way. It lets you transform your traditional publication material to an online experience. The tool, called ePublisher, is very feature-rich and is attracting a lot of attention. You can input your material in PDF format to the application and it will generate online content. You can then enrich the content with extra functionality, such as supporting sharing in social networks and adding music, video, search, and print. The challenge with the Publitas software is that its existing customers are established and well-known businesses that are sometimes already so powerful that exposure ratings resemble those of a mass medium like television.

Audience

Of course, we welcome all readers of this book, and we hope it inspires you to get into AWS and utilize it in the best possible way to be successful. But we set out to write this book with a particular purpose: to be an AWS guide for building and growing applications from small to "Internet scale." It will be useful if you want to host your blog or small web application, but it will also help you grow like Zynga did with Farmville. (Some say Zynga is the fastest growing company in the world.)

This book does not focus on detail; for example, we are not going to tell you exactly which parameters each command receives, and we are not going to list all the available commands. But we will show you the approach and implementation. We rely on examples to illustrate the concepts and to provide a starting point for your own projects. We try to give you a sense of all AWS functionality, which would be nearly impossible if we were to show the details of every feature.

To get the most out of this book, you should be comfortable with the command line, and having experience writing software will be useful for some of the chapters. And it certainly wouldn't hurt if you know what Ubuntu is (or CentOS or Windows 2003, for that matter) and how to install software. But most of all, you should simply be curious about what you can do with AWS. There's often more than one way of doing things, and since AWS is so new, many of those ways have not yet been fully explored.

If you are a seasoned software/systems engineer or administrator, there are many things in this book that will challenge you. You might think you know it all. Well, you don't!

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Of course, you need “strange eyes” going over every detail and meticulously trying out examples to find errors. Our technical reviewers, Anthony Maës, Ben Immanuel, Graziano Obertelli, and Menno van der Sman, did just that.

And finally, there is the wonderful and extremely professional team at O'Reilly. Without Mike, Julie, and all the others there wouldn't even have been a book. To Amy Thomson, Adam Zaremba, Julie Steele, Mike Loukides, Sumita Mukherji, and the rest we met and worked with, thank you!

Introducing AWS

From 0 to AWS

By the late 1990s, Amazon had proven its success—it showed that people were willing to shop online. Amazon generated \$15.7 million in sales in 1996, its first full fiscal year. Just three years later, Amazon saw \$1.6 billion in sales, and Jeff Bezos was chosen Person of the Year by Time magazine (<http://www.time.com/time/subscriber/personoftheyear/archive/stories/1999.html>). Realizing its sales volume was only 0.5% that of Wal-Mart, Amazon set some new business goals. One of these goals was to change from shop to platform.

At this time, Amazon was struggling with its infrastructure. It was a classic monolithic system, which was very difficult to scale, and Amazon wanted to open it up to third-party developers. In 2002, Amazon created the initial AWS, an interface to programmatically access Amazon's features. This first set of APIs is described in the wonderful book *Amazon Hacks* (<http://oreilly.com/catalog/9780596005429>) by Paul Bausch (O'Reilly), which still sits prominently on one of our shelves.

But the main problem persisted—the size of the Amazon website was just too big for conventional (web) application development techniques. Somehow, Jeff Bezos found Werner Vogels (now CTO of Amazon) and lured him to Amazon in 2004 to help fix these problems. And this is when it started for the rest of us. The problem of size was addressed, and slowly AWS transformed from “shop API” to an “infrastructure cloud.” To illustrate exactly what AWS can do for you, we want to take you through the last six years of AWS evolution (see Figure 1-1 for a timeline). This is not just a historical journey, but also a friendly way to introduce the most important components for starting with AWS.

AWS has two unique qualities:

- It doesn't cost much to get started. For example, you don't have to buy a server to run it.

Of course, he doesn't know that this whole project was based on a precondition of audio-only; neither does the CEO.

In the morning, she calls the project manager and explains her idea. She is still full of energy and says enthusiastically, "the functionality is 100% perfect, only we want audio *and* video." The project manager knows about the precondition, and he also knows that video files are significantly bigger than audio files. However, the CEO doesn't want to hear buts and objections about moving away from the plan; she wants this product to change before launch.

In Short

In this chapter we walked you through the recent history of AWS. We showed how each of the AWS services was created to solve a particular problem with Amazon's platform. We gave you a brief overview of the different AWS services you can use to build, monitor, and scale your cloud infrastructure. And finally, we talked about how developing with AWS is naturally agile and allows you to make the infrastructure building and running part of the development process.

In the rest of the book, we'll show how all these services actually work, so get ready to stop reading and start doing! In the next chapter, we will start with migrating a simple web application to AWS using EC2, RDS, S3, and CloudFront.

Growing with S3, ELB, Auto Scaling, and RDS

We have done quite a lot in just a couple of chapters. We have explored what it means to design, build, and operate virtual infrastructures on AWS. We have looked at the opportunities it provides, and we have moved a real-world application, Kulitzer.com, to AWS. Although we have done many things that are usually very difficult on physical infrastructures, we have not yet looked at the biggest benefit of AWS: an *elastic* infrastructure that scales with demand.

With growing traffic, our initial setup will soon be insufficient. We know we can *scale up* with bigger machines, but we prefer to *scale out*. Scaling up is OK in certain situations. If you have a fixed upper limit in traffic—for example, if your users are internal to an organization—you can safely assume it is not necessary to go through the trouble of implementing load balancing and/or autoscaling. But if your application is public, and perhaps global, this assumption can be costly. Scaling up is also manual on AWS, requiring reboots and temporary unavailability of your instance. The same goes for the opposite, scaling down (Figure 3-1).

Scaling out, on the other hand, requires changes to your application. You have to make sure you can have several instances doing the same work, preferably on their own. If the instances can operate in their own context, it doesn't matter if you have three or seven instances. If this is possible, we can handle traffic with just the right number of instances. If the traffic increases, we launch some more instances; if the traffic decreases, we terminate some of the instances.

We don't have to worry about scaling out the presentation layer (recall the three-tier architecture introduced in the previous chapter). We use S3/CloudFront, which does all the scaling out and scaling in for us. And even if you chose to implement your own infrastructure for this, it is not that hard. Making the logic layer elastic is a bit harder, but not impossible. You basically have to *make sure all of the data the application server works on that needs to be shared by other application servers does not reside on the application server itself*. Think of sessions, for example, or user content. But the data

There is one more feature worth mentioning, and that is deployment. EB allows you to manage versions of your application. Deployments happen on a running EB cluster (for lack of a better name). If things do not go as planned, you can easily choose another version to deploy, for example when you want to do a rollback. This might just be the killer feature of Elastic Beanstalk.

Even though this service has just been released, it will surely prove useful in helping you get up and running quickly. And if you outgrow the Elastic Beanstalk way of deploying your application, you can start to take over one step at a time.

In Short

In this chapter, we started taking advantage of the elasticity property of AWS infrastructures. On one hand you can scale up manually, changing to bigger instances. However, you can also scale *out* by using more instances, and AWS provides ways of automating this. Before you can set up your infrastructure to scale out, though, you need a way to put your data somewhere so it can be shared. We explored different ways to do this, and showed an example of using S3 for user uploaded data.

The two most important new components we introduced in this chapter are ELB and Auto Scaling. You can use these components together to set up an autoscalable infrastructure. By specifying a few rules, you can determine when your infrastructure will scale out by launching new instances, or scale in by terminating instances when load is reduced again, for example. We also discussed using Auto Scaling without an ELB to make your application more resilient by monitoring an instance and launching a new one when it fails.

We then focused on scaling relational databases. We showed how easy it is to scale an RDS instance up and down by choosing another instance class. For scaling out, we have the option of read replicas. In both cases, using multi-AZ RDS reduces or removes downtime when you make modifications to the RDS machines.

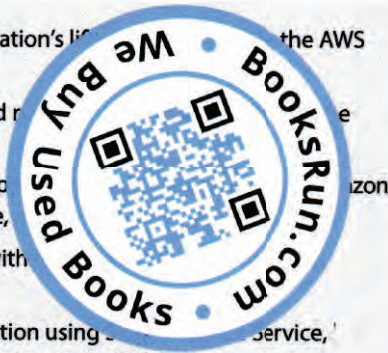
Finally, we gave a brief overview of the Elastic Beanstalk tool, which helps you set up a scalable application very quickly using EC2, Auto Scaling, ELB, S3, and SNS.

Programming Amazon EC2

If you plan to use Amazon Web Services to run applications in the cloud, the end-to-end approach in this book will save you needless trial and error. You'll find practical guidelines for designing and building applications with Amazon Elastic Compute Cloud (EC2) and a host of supporting AWS tools, with a focus on critical issues such as load balancing, monitoring, and automation.

How do you move an existing application to AWS, or design your application so that it scales effectively? How much storage will you require? *Programming Amazon EC2* not only helps you get started, it will also keep you going once you're successfully positioned in the cloud. This book is a must-read for application architects, developers, and administrators.

- Determine your application's life cycle and the AWS tools you need
- Learn how to build and manage your application development process
- Migrate simple web applications to Amazon Simple Storage Service, Amazon ElastiCache, and Amazon CloudFront
- Meet traffic demand with Amazon ElastiLoad Balancing
- Decouple your application using Amazon SQS, Amazon SNS, Simple Notification Service, and other tools
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"Jurg and Flavia have done a great job in this book building a practical guide on how to build real systems using AWS."

—Werner Vogels
VP & CTO at Amazon.com

Jurg van Vliet co-founded 9Apps, an AWS solution provider and silver partner of Eucalyptus. He worked for various web startups and media companies before starting the e-learning firm 2Yellows.

Flavia Paganelli, co-founder of 9Apps, has been developing software over the past 14 years for several industries while working at companies such as TomTom and Layar. She is the creator of the Decaf EC2 smartphone app.

Previous programming experience is recommended.

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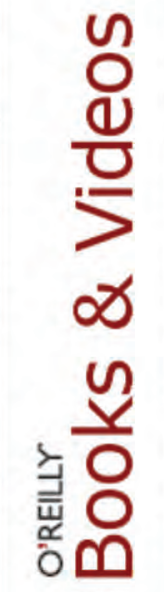
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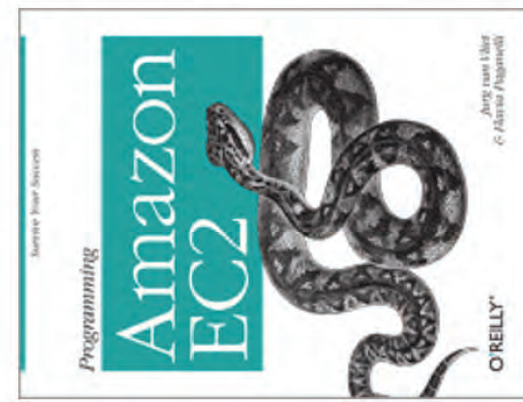
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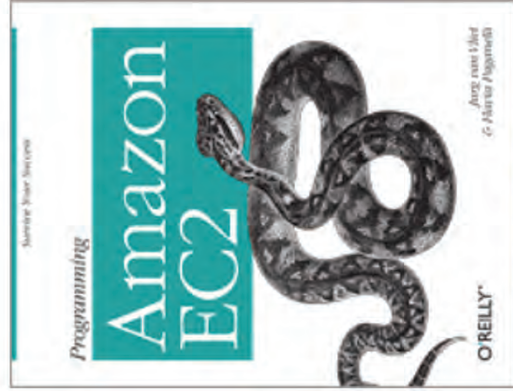
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Programming Amazon EC2

Run Applications on Amazon's Infrastructure with EC2, S3, SQS, SimpleDB, and Other Services

By

[Jurg van Vliet](#), [Flavia Paganelli](#)

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Description

If you plan to build applications to run on Amazon's Web Services, the end-to-end approach in this book will save you needless trial and error. You'll find practical guidelines for designing and building applications with Amazon Elastic Compute Cloud (EC2) and a host of supporting AWS tools, with a focus on critical issues such as load balancing, monitoring, and automation.

Full Description

If you plan to use Amazon Web Services to run applications in the cloud, the end-to-end approach in this book will save you needless trial and error. You'll find practical guidelines for designing and building applications with Amazon Elastic Compute Cloud (EC2) and a host of supporting AWS tools, with a focus on critical issues such as load balancing, monitoring, and automation.

How do you move an existing application to AWS, or design your application so that it scales effectively? How much storage will you require? *Programming Amazon EC2* not only helps you get started, it will also keep you going once you're successfully positioned in the cloud. This book is a must-read for application architects, developers, and administrators.

- Determine your application's lifecycle and identify the AWS tools you need
- Learn how to build and run your application as part of the development process
- Migrate simple web applications to the cloud with EC2, Amazon Simple Storage Service, and CloudFront content delivery
- Meet traffic demand with EC2's Auto Scaling and Elastic Load Balancing
- Decouple your application using Simple Queue Service, Simple Notification Service, and other tools
- Use the right tools to minimize downtime, improve uptime, and manage your decoupled system

"Jurg and Flavia have done a great job in this book building a practical guide on how to build real systems using AWS."

--Werner Vogels, VP & CTO at Amazon.com

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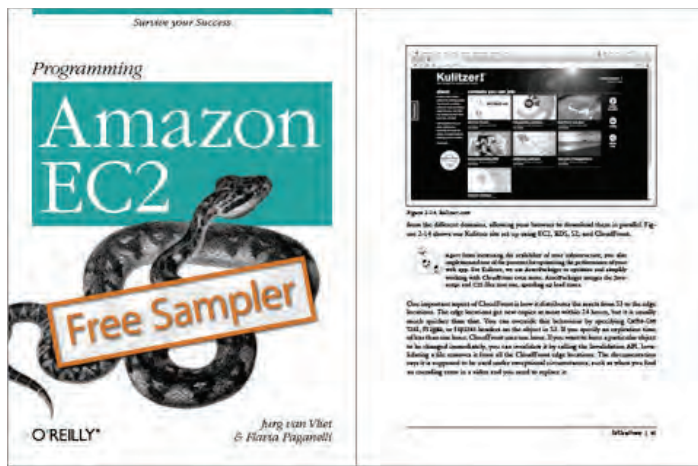
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Flavia Paganelli has been developing software in different industries and languages for over 14 years, for companies like TomTom and Layar. She moved to The Netherlands with her cat after finishing an MSc in Computer Science at the University of Buenos Aires. A founder of 9Apps, Flavia loves to create easy-to-understand software that makes people's lives easier, like the Decaf EC2 smartphone app. When she is not building software, she is probably exercising her other passions, like acting or playing capoeira.

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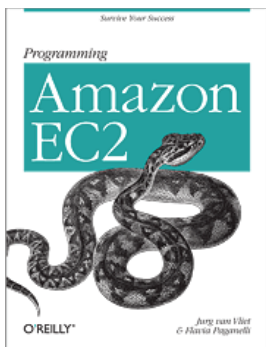
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The animal on the cover of *Programming Amazon EC2* is a bushmaster snake. A member of the genus *Lachesis*, it may belong to any of the three recognized bushmaster species: *Lachesis muta*, *Lachesis stenophrys*, and *Lachesis melanocephala*. Each resides in the forested regions of Central and South America, particularly the Amazon River basin.

Collectively, bushmasters are known to be the longest venomous snakes in the world; the average length is 6 to 8 feet, though exceptional specimens have been noted to grow upward of 10 feet. The snakes are reddish-brown in appearance, and sport some variety of X or diamond patterns across their backs, as well as spines at the end of their tails.

As a type of pit viper, bushmasters will often lay in wait for prey to appear for weeks at a time; depending on the size of captured prey, the snakes can survive on as few as 10 meals per year. Bushmasters are also thought to be the only New World pit vipers to lay eggs, as opposed to giving birth to live young. Females have been known to remain with the nest during incubation and to defend it if approached.

Bushmasters have at least one claim to fame: their genus, *Lachesis*, is named for one of the three Fates in Greek mythology. Lachesis, known as the drawer of lots, was tasked with determining individuals' life spans by measuring every person's thread of life against her measuring rod.



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EXHIBIT 1014A

◆ Facial Image Recognition Based on Fractal Image Encoding

Xiutao Tang and Cuilu Qu

Fractal image encoding uses self-similarity to encode an image. Utilizing this feature, a new method of facial image recognition based on fractal image encoding is examined. Fractal image encoding can approximate any given image by capturing intrinsic self-similarity within the image. This method has some invariance to rotation, scaling, translation, and luminance. The method encodes an image of record through the use of an encoding dictionary composed of images in a face image database. The fractal codes are then placed in a file, and the fractal codes are iterated multiple times to obtain decoding images. By comparing the peak signal-to-noise ratio of the image of record to all the decoding images, the image in the image database whose decoding image minimizes this norm is the recognized image. By experiment, the recognition performance achieved by this new method posted an average recognition rate of 94.54 percent on the publicly available database of faces hosted by the Cambridge University Computer Laboratory Digital Technology Group, when facial images at a side profile orientation are within 15 degrees of a full frontal image. © 2010 Alcatel-Lucent.

Introduction

Facial image recognition relies significantly on the application and development of pattern recognition algorithms. At present, most of the research work in this area is only at the beginning stage. Facial image recognition presents many difficulties, as described in [2]. For example, the face is not a rigid entity; it contains complicated and abundant expression, so strict feature matching is ineffective. In addition, the data associated with a facial image is usually quite substantial, so storage requirements for input data can be considerable. In fact, if the face pattern is unrestricted, input data may assume exponential proportions.

There are two methods by which a computer can recognize a facial image: first, via local features and relationships such as eyes, nose, and mouth [8, 9], and second, by a statistical analysis of facial features as

a whole [3, 5]. To date, the global facial expression has proven to be of only limited use in facial image recognition.

Teewoon Tan developed a face image recognition method based on fractal image encoding [4]. He first proposed that an “image of record” could be matched with another facial image in a face image database. All facial images in the face image database were then encoded, and the fractal codes were saved within the database. For the process of recognition, fractal codes were iterated a single time to obtain decoding images, and the decoding images were then compared to the neighbor distance of the image of record to obtain image recognition. The main idea was to filter high frequency information such as changes of expression through fractal encoding and a single iterative decoding,

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and then to compare the difference between the two facial images. Although this method filters high frequency information by fractal transformation, the recognition rate is not significantly improved.

Utilizing the feature of self-similarity, a new method of facial image recognition based on fractal image encoding is studied. This method encodes an image of a face for the purposes of recognition through the use of an encoding dictionary composed of all images in the facial image database. Fractal codes for the image are placed in a file, and the codes are iterated multiple times to obtain decoding images. By comparing the peak signal-to-noise ratio (PSNR) of the image of record to all the decoding images, the image in the image database whose decoding image minimizes this norm is the recognized image. By experiment, the recognition performance of this new method achieved an average recognition rate of 94.54 percent using the publicly available Cambridge University database of faces [1], when the face's side profile image was within 15 degrees of a full frontal image.

Principle of Fractal Image Encoding

Through research and analysis of a large number of images, Wei, Shen, and Li have shown in [6] that there is self-similarity between a local image and an image as a whole, as well as self-similarity in different parts of an image. Fractal image encoding develops an iterative function system (IFS) [7] by focusing on the self-similarity in the image. The process of developing an IFS for the image begins by creating a sub-block self-affine contraction to approximate another sub-block in the image. The decoding process utilizes the collage theorem to enable the IFS that can capture the image to iterate the initial image multiple times to reconstruct an approximate image.

To obtain the IFS of an image, we divide the image into non-overlapping range blocks. For each range block, we then search the domain block that is most similar to the range block by an affine transform and gray transform.

Basic Algorithm of Fractal Image Encoding

The fractal image encoding algorithm is as follows:

1. The image is divided into non-overlapping blocks of size $B_{\max} \times B_{\max}$, named range blocks.

Panel 1. Abbreviations, Acronyms, and Terms

IFS—Iterative function system
PSNR—Peak-signal-to-noise ratio
rms—Root mean square

2. The image is divided into non-overlapping blocks of size $D_{\max} \times D_{\max}$, named domain blocks, usually $D_{\max} = 2B_{\max}$.
3. Block D_i , of size $D_{\max} \times D_{\max}$ is transformed and classified into three major categories and 24 sub-categories by the gray value and the variance of block D_i .
4. Each range block R_i is classified into three major categories and 24 subcategories by the gray value and the variance of block R_i . Next, search for the block D_i which can match block R_i best (usually there are many D_i blocks in the same class) from the same class of block R_i and compute the *rms* between the best matching block D_i and block R_i . If the *rms* is smaller than the given value, record the related parameters.
5. Otherwise, divide block R_i by a quad tree, and return to step 3.
6. End.

As shown in **Figure 1**, Image A is the image of record. Image B and Image C are other images in the facial image database. Image B is the same person as Image A with a different posture. Image C is a different person from Image A.

1. Image A uses itself as the encoding dictionary and generates fractal codes.
 - Image (a-1) is the decoding image that iterates fractal codes one time,
 - Image (a-2) is the decoding image that iterates fractal codes two times,
 - Image (a-3) is the decoding image that iterates fractal codes three times,
 - Image (a-4) is the decoding image that iterates fractal codes five times.
2. Image A uses Image B as the encoding dictionary and generates fractal codes.
 - Image (b-1) is the decoding image that iterates fractal codes one time,

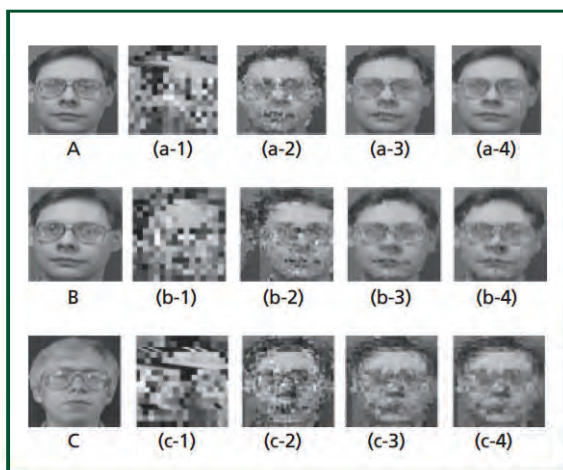


Figure 1.
Facial image recognition based on fractal image encoding.

- Image (b-2) is the decoding image that iterates fractal codes two times,
 - Image (b-3) is the decoding image that iterates fractal codes three times,
 - Image (b-4) is the decoding image that iterates fractal codes five times.
3. Image A uses Image C as the encoding dictionary and generates fractal codes.
- Image (c-1) is the decoding image that iterates fractal codes one time,
 - Image (c-2) is the decoding image that iterates fractal codes two times,
 - Image (c-3) is the decoding image that iterates fractal codes three times,
 - Image (c-4) is the decoding image that iterates fractal codes five times.

After five iterations of the same person with different facial images—detailed in step 2 above, where Image A uses Image B as the encoding dictionary—the decoding image, image b-4, is very similar to Image A, which is the image of record. However, given the images of two different persons—where Image A uses Image C as the encoding dictionary—the decoding image, image c-4, is unclear, and there are many small blocks in the image.

Table I. PSNR calculations.

	Image (a-4)/ Image A	Image (b-4)/ Image A	Image (c-4)/ Image A
PSNR	34.215244	25.437908	17.738887

PSNR—Peak signal-to-noise ratio

We then compute the PSNR, as shown in **Table I**. The PSNR between image (a-4) and Image A is 28.76, while the PSNR between image (b-4) and Image A is 23.73. Meanwhile, the PSNR between image (c-4) and Image A is 17.59. Image A is the image of record in the image database, while Image B is obviously the “recognized” image. By using the PSNR, we can recognize images of the same person with different expressions and different postures.

Face Image Recognition: Experiment Steps

Cambridge University maintains a database of faces containing a set of facial images captured between April 1992 and April 1994 [1], which was used in the experiment. There are 400 facial images of 40 persons with different expressions and different postures. **Figure 2** provides a representative sample of images.

Steps:

1. The image of record is the input image, and the images in the image database are the encoding dictionary (assuming there are n images in the database). The image of record is encoded by an encoding dictionary composed of images in the image database, which then provides n “.dat” files.
2. The n “.dat” files are iterated five times by the fractal image decoding program, which provides n decoding images.
3. The method of image recognition:

The PSNR—the peak signal-to-noise ratio between the image of record and the decoding image—is the quantitative measurement. The images whose PSNR is higher than the threshold value are the recognized images. If all PSNR values are lower than the threshold value, then there is no image of the same person with an image of record in the face image database.

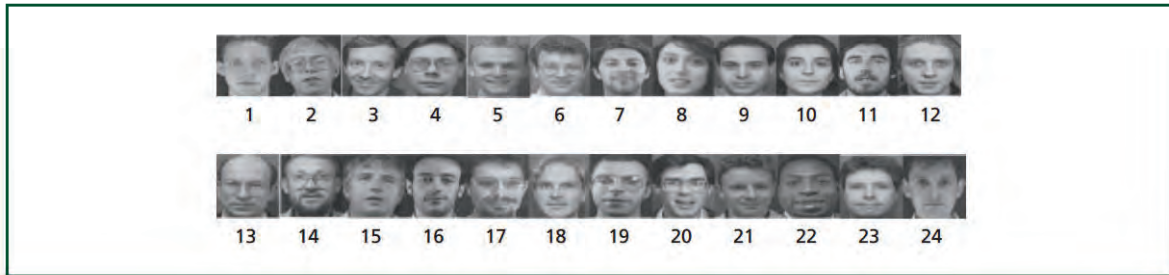


Figure 2.
Images in the image database.

$$PSNR = 10 \log_{10} \frac{M \times N \times 255^2}{\sum_{m,n} (s_{m,n} - \bar{s}_{m,n})^2} \quad (1)$$

$s_{m,n}$ is the gray value of the (m, n) pixel of the image of record, $\bar{s}_{m,n}$ is the gray value of the (m, n) pixel of the decoding image in the database, M is the height of the image, N is the width of the image.

Experiment Results

As shown in **Table II**, since the PSNR between image (a-24) and Image A is the highest, image (a-24) is obviously the recognized image of Image A. That is, image (a-24) is the same person who appears in

Image A with a different expression and different posture. As shown in **Table III**, since the PSNR between image (b-8) and Image B is the highest, image (b-8) is the recognized image of Image B. That is, image (b-8) is the same person who appears in Image B, with a different expression and different posture.

The time necessary for recognition is shown in **Table IV**.

Facial image recognition based on fractal image encoding compares favorably to the 94.54 percent recognition rate for images within the Cambridge University database of faces, with a side profile facial orientation within 15 degrees of a full frontal image.

Table II. PSNR for Image A.

Decoding image	PSNR with Image A	Decoding image	PSNR with Image A	Decoding image	PSNR with Image A
a-1	19.816535	a-9	19.970701	a-17	20.264797
a-2	22.508474	a-10	19.452519	a-18	17.744489
a-3	20.482979	a-11	21.286626	a-19	20.531052
a-4	20.190718	a-12	19.818913	a-20	21.079812
a-5	18.050826	a-13	17.211404	a-21	19.391354
a-6	16.788616	a-14	19.881216	a-22	20.618953
a-7	21.518394	a-15	21.392740	a-23	19.515317
a-8	18.573199	a-16	22.135498	a-24	23.953833

PSNR—Peak signal-to-noise ratio

Table III. PSNR for Image B.

Decoding image	PSNR with Image B	Decoding image	PSNR with Image B	Decoding image	PSNR with Image B
b-1	18.700903	b-9	21.834658	b-17	20.410737
b-2	20.115239	b-10	19.723254	b-18	19.514059
b-3	20.556330	b-11	21.773027	b-19	19.224120
b-4	20.683712	b-12	20.226770	b-20	19.582266
b-5	20.066220	b-13	15.855981	b-21	19.715886
b-6	19.420714	b-14	19.583121	b-22	19.370194
b-7	19.739001	b-15	20.158694	b-23	20.067946
b-8	27.381136	b-16	19.386892	b-24	20.486557

PSNR—Peak signal-to-noise ratio

Table IV. Time required for recognition.

Number of images in the image database	Time required for recognition (seconds)
50	9.64
100	16.905
200	33.421
300	45.515
400	66.468

Conclusions

This paper studies a new method of facial image recognition based on fractal image encoding. The method takes an image of record and encodes it via an encoding dictionary composed of images in a face image database to obtain fractal codes, which are then placed in a file. We iterate the fractal codes multiple times to obtain a decoding image, and then compare the PSNR between the image of record and the decoding images. The experiment shows that the method provides a favorable rate of recognition since it uses self-similarity within the facial image to eliminate the effects of expression and posture.

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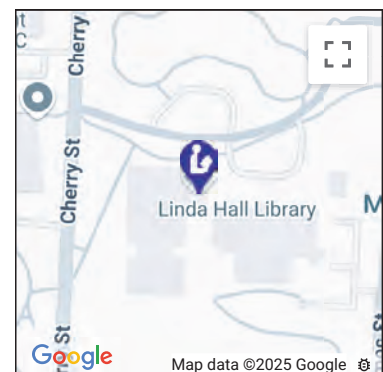
Organizational structure: The library is part of a **privately-funded** organization. It operates on a **Non-profit** financial model.

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Annual Circulation	30,000	transactions

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Tuesday	9:00 am	5:00 pm
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Linda Hall Library



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Serial Publication Year: 2010

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Frequency: Quarterly.

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Tang, X., & Qu, C. (2010). Facial image recognition based on fractal image encoding. *Bell Labs Technical Journal*, 15(1), 209-214.

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