LEECH: BITTORRENT AND MUSIC PIRACY SONIFICATION

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ABSTRACT

This paper provides an overview of a multi-media composition, *Leech*, which aurally and visually renders BitTorrent traffic. The nature and usage of BitTorrent networking is discussed, including the implications of wide-spread music piracy. The traditional usage of borrowed musical material as a compositional resource is discussed and expanded upon by including the actual procurement of the musical material as part of the performance of the piece.

The technology and tools required to produce this work, and the roles that they serve, are presented. Eight distinct streams of data are targeted for visualization and sonification: Torrent progress, download/ upload rate, file name/ size, number of peers, peer download progress, peer location, packet transfer detection, and the music being pirated. An overview of the methods used for sonifying and and visualizing this data in an artistic manner is presented.

1. INTRODUCTION

The internet has altered the manner in which we as individuals live our daily lives. Like any technology, the internet can be used for both positive and negative applications. Global communications allows families living in far off lands to connect and bond over vast distances. However, that same capability may also be used by nefarious forces to coordinate violent activities. One prominent ramification of networking technologies is music piracy. According to a recent survey commissioned by NBC Universal as much as 23.76% of all internet traffic infringes upon copyright [1]. This represents a rather substantial proportion, throwing into question just what exactly our society deems as acceptable behavior. The combination of MP3s, ipods, the internet, and the push for ”singles” by record companies have all led to a commoditization of music. With this commoditization has come a reevaluation in our society of the monetary value of musical content.

One of the catalysts that has led to such a high level of piracy is a peer-to-peer networking technology known as BitTorrent [2]. This technology was not initially intended to be used for exchanging pirated content; BitTorrent is indeed used in the distribution of many completely legal downloads, including open source software and commercial video games. However, according to the previously mentioned study it is estimated that approximately 63.7% of all BitTorrent traffic infringes copyright.

To help illustrate the moral and physical dynamics of music piracy a new multi-media composition, entitled *Leech*, has been constructed. *Leech* includes components of sonification and music composition, using the actual mechanisms that enable BitTorrent downloads as mined data for real-time algorithmic sound production. Network data and structure is mapped in musically and visually meaningful ways to produce an experience that embodies the look and sound of piracy. Furthermore, the actual music being pirated is itself used as a resource for audio processing and music composition. Performed in real-time, the composition provides multi-factorial insight into the world of music piracy as it happens that very moment. For reference, a video capture of a performance of *Leech* can be found at `http://vimeo.com/21603631` [3].

2. GOALS AND AESTHETICS

There are two main goals that drove the development of *Leech*. The first goal is to be sensuously arresting and interesting. *Leech* is conceptualized as a multi-media composition, not just a simple sonification. Thus it should be able to stand on its own as a composition in and of itself. The second goal of *Leech* is to make people think. No judgement is passed on the activities, legal or not, of the pirates, record companies, or musicians involved. Rather, the goal is to illuminate an often overlooked and dismissed part of modern day culture, and to spark a dialog about the nature and value of music and sharing.

Central to these goals is the often conflicting relationship between sonification and composition. If executed well, a visually and sonically interesting composition can draw attention to a subject being sonified. If done poorly, these elements may distract or even put off. Thus a strong compositional hand is required to make the experience enjoyable and thought provoking. However, if there is too strong an aesthetic influence then the data being sonified can be lost completely among the intuitive parameters of the piece.

Thus the reasoning for mapping particular pieces of data to different musical and visual parameters becomes a compromise between intuition and transparency. Table 1 shows an overview of how the different data types in a BitTorrent download are sonically and visually mapped in *Leech*. This will be covered more in depth in Section 6 and Section 7.

3. HISTORICAL PRECEDENT

3.1 Borrowed Sounds

The concept of using copyrighted audio as a musical resource for quotation and variation is not a new one. Early electronic music composers such as Edgard Varese and Iannis Xenakis borrowed musical material using analog tape. James Tenny used samples of Elvis Presley's "Blue Suede Shoes" in his composition *Collage #1* in 1961 [4]. With the advent of digital samplers in the 80's, using copyrighted material became even more commonplace. John Oswald explored the usage of popular music as a compositional resource in his album *Plunderphonics* [5]. Hiphop artists such as Public Enemy and Biz Markie embraced the practice of sampling, and were given almost free-reign until the once underground musical style started to become profitable for record labels. Since then record companies have formed whole departments dedicated to finding copyright infringing samples in newly released songs [6].

Leech attempts to take this idea of borrowed musical material a step forward, to make transparent not only the usage of the material, but also the procurement of it as well. John Cage's works *Radio Music* and *Imaginary Landscapes #4* are especially relevant in this regard. These works explore capturing radio signals and noises from the electromagnetic spectrum, using these sounds as musical materials in real-time. This technique is quite similar to the system used by *Leech*, which captures sounds and data from packet streams on a peer to peer network. However, *Leech* has the added foil of explicit illegality. This is a rather appropriate attribute in a day and age where illegally sharing musical experiences is commonplace.

3.2 Sonification

Sonification is often understood to be a scientific activity, primarily aimed at finding another means for understanding a complex data set. In his book *Auditory Display: Sonification, Audification, and Auditory Interfaces* Gregory Kramer describes sonification as "the mapping of numerically represented relations in some domain under study to relations in an acoustic domain for the purpose of interpreting, understanding or communicating relations in the domain under study" [7]. However many composers have approached sonification as a more artistic activity, not necessarily devoted to attempting to provide purely intellectual clarity to a data set, but instead using it as a musical resource to drive a composition.

Early examples of this include *Reunion* by John Cage, which uses a chess board as an audio mixer, and *Music for Solo Performer* by Alvin Lucier, which involves amplifying brainwaves to the point of acoustically activating percussion instruments. Marty Quinn investigates sonification of natural forces in multiple works, including *The Climate Symphony* which generates gamelan-esque rhythmic music based on the pulsating climatological history of the earth, and *Rain*, which converts the intensity of ice melting over time into pitch and rhythm for percussive sounds. Bob Sturm uses the undulations of the ocean's waves in his piece *Music from the Ocean* to drive electronic music, creating 34 different data mappings to produce individuals musical tracks [8]. Especially pertinent to *Leech* is the piece *Network Sonification* by Zach Layton, which crawls websites, examining their link and data structures, converting this data into a kind of aural snapshot of their network topology [9].

Mined Data	Mapping
Torrent Progress(%)	Timbral Complexity
Download/UploadRate(kB/s)	Envelope Attack time
File Names/Sizes(mB)	Visual presentation
Number of Peers(int)	Visual presentation
Leecher vs. Seeder(%)	Synthesis Type
Peer Location(ϕ/λ)	Pitch/Timbre
Packet Transfer(ϕ/λ)	Pitch/Timbre
MP3	Processed Playback

Table 1. Mined data and a brief overview of how they are mapped.

4. TECHNOLOGICAL OVERVIEW

Leech involves several interlocking open source technologies. The visuals and logical systems are developed with the Java programming language [10]. The BitTorrent transfers are accomplished using the OSX application Transmission [11]. Analyzis of transfer traffic is executed with the Java library Jpcap [12]. Geographic placement of peers is derived using the freely-distributed version of Max Mind's GeoLite City [13].

Visual representation and GUI elements are developed with the Processing programming language, used as a library from within Java [14]. Sound is produced with the real-time sound synthesis programming language SuperCollider [15]. Communications between Processing and SuperCollider is accomplished with the Open Sound Control (OSC) protocol [16]. LAME is used to convert partially completed MP3 downloads and load them into SuperCollider for audio processing [17].

5. DATA MINING

The basis for all of the visual and musical content in *Leech* is derived from data-mining. Therefore it is the data-mining technologies that are the core engine of the whole system, driving the flow of the entire experience. There are three distinct modules that act in coordination to derive information about the BitTorrent transfer:

5.1 Torrent Control

The first module is a Remote Procedure Calls (RPC) communication layer that controls and queries the Transmission BitTorrent Client. Through individual calls to Transmission the module can control the torrent download by starting and stopping the transfer, altering the number of peers to download from, and increasing or decreasing transfer speed. Data can be requested about the download, in-

Mined Data	Module
Torrent Progress(%)	Torrent Client
Download/UploadRate(kB/s)	Torrent Client
File Names/Sizes(mB)	Torrent Client
Number of Peers(int)	Torrent Client
Leecher vs. Seeder(%)	Torrent Client
Peer Location(ϕ/λ)	Torrent Client/GeoLite
Packet Transfer(ϕ/λ)	GeoLite/JPCap
MP3	Torrent Client/Lame

Table 2. Mined data and the modules used to derive them

cluding ip addresses of peers, name and size of the torrent files, download rate, and progress of download.

5.2 Geolocation

The second module utilizes the IP address database GeoLite City. This database contains the geographic location of most of the distributed IP addresses on the internet. Regularly updated, the freely distributed version is accurate to the city level in most cases, which is more than adequate for the purposes of this piece. By cross referencing this database with the IP addresses obtained from Transmission, it is possible to geographically place the peers that are transferring pirated audio.

5.3 Packet Capture

The third data-mining module monitors internet traffic on the local machine, capturing each packet of information that is being transferred to and from the localhost. From these packets of information it is possible to derive the sending and receiving IP address and payload information. By cross referencing this module with the previous two modules it is possible to derive when a packet of pirated BitTorrent information is being transferred between the localhost and particular peer. This information may then be depicted geographically, and sonically rendered.

6. MAPPING DATA

Leech is a multi-media composition, and thus it is not merely enough to derive the characteristics of a torrent download. Mapping this information in a visually and musically meaningful way is the challenge of the entire composition. The basic visual backdrop is a vectorized world map, upon which all other mined information is depicted(See Appendix A).

6.1 Peer Mapping

Using the three data-mining modules it is possible to derive several characteristics of a peer. A peer's geographic location, download progress, and when they are sharing pirated information can all be derived. Using Processing, the geographic location of a peer is rendered visually as a pulsating ellipse placed geographically on a vectorized world map. The color of the ellipse denotes the progress of the peer's own torrent download. A peer with less than 100% downloaded is represented with a white ellipse, and is referred to as a "leecher". A peer that has finished downloading and is currently only uploading data is represented with a green ellipse and is referred to as a "seeder". Currently there is no static sonification of a peer's geographic position, or when a peer is added to the system. Instead these parameters are sonified in conjunction with other mapping systems described later.

6.2 Transfer Progress Mapping

The overall progress of the BitTorrent download and the individual progress of each MP3 transfer are also mapped visually and sonically. On the left hand side of the screen a series of bright blue bars are shown extending horizontally towards the center. As the transfer progresses to completion these bars extend further out. The names of each MP3 being downloaded is displayed over their respective bar to show their respective download progress. Sonically, these values are mapped much more directly than the packet transfer sounds, and it is much more easily cognizable to hear the effect of the download on these sounds.

One synth is produced for each individual MP3 being downloaded, usually in the range of 10 to 15 depending on the size of the album being downloaded. These sounds undulate as a kind of ambient background to the piece. As the download progresses from the beginning to completion several characteristics of the sound are modulated. High frequency content, undulation speed, feedback amount, and general timbral complexity all increase as the download progresses.

Figure 1 shows a snippet of SuperCollider code mapping file transfer data to synthesis parameters. Depicted is a Gendy stochastic oscillator, a concept conceived by composer Xenakis in his treatise *Formalized Music* [18]. Unlike periodic oscillators that oscillate linearly, this oscillates based upon a given distribution of probabilities. The oscillator is being deployed in sinus mode, which means that it is sampling an outside oscillator to provide a constantly shifting probabilistic distribution. The third and fourth inputs are the external oscillators being sampled, which are themselves Gendy oscillators(not depicted here). Inputs five and six determine the frequency of the oscillator. Very simply, as the download progresses, the pitch goes up. The final slot depicts the number of control points sampled during one period of oscillation. As the download progresses, the amount of control points sampled per period increases, thus increasing high frequency content and timbral complexity. This demonstrates a very direct influence of the download being exerted on the sound. The staggered progression of each file transmission produces a heterophonic texture that moves as a loosely connected cloud from relative timbral simplicity to more intense and complex tonal emissions. This is useful in giving an overall form and shape to the piece.

6.3 Packet Capture Mapping

Each time a packet of information is identified as being part of the torrent download, the system identifies the parties sending and receiving the pirated information. This

```
osc3 = Gendy4.ar(
     6,//Sinus Mode
     6,//Sinus Mode
     osc1,//Sampled Oscillator
     osc2,//Sampled Oscillator
     fileProgress.linlin(0,1,520,47000),//Min Freq
     fileProgress.linlin(0,1,520,47000),//Max Freq
     initCPs: 100,//Initialized Control Points
     knum:fileProgress.linlin(0,1,40,100).round(5)
);
```

Figure 1. File transfer sonification code in SuperCollider.

determines whether or not the localhost is downloading or uploading information, and to whom they are uploading to or downloading from. Furthermore, by cross referencing against the attributes of the peer involved, it is possible to depict whether the transfer involves a seeder or a leecher. Using these parameters the system organizes packet transfers into four subtypes: downloads from leechers (DL), uploads to leechers, (UL) downloads from seeders (DS), and uploads to seeders (US).

Whenever a packet transfer is identified it is rendered visually as a colored curve stretching from the localhost to the peer involved. The orientation and color of the curve depict what type of transfer it is. A DL transfer is a white line curving upwards. UL transfers are white and curve downwards. DS transfers are green and curve upwards. US transfers are blue and curve downwards. This information is also passed to SuperCollider via OSC to be rendered sonically.

In SuperCollider there are four types of synthesized sounds that are produced based upon the four packet transfers types. Characteristics of the packet transfer are also used to further modulate the characteristics of these sounds. Download rate, local transfer progress, peer transfer progress, and peer latitude and longitude are all characteristics that influence the synthesized sounds. Due to the large quantity of packet transfers throughout the course of a twenty minute performance, emphasis is placed more on variety of results rather than on simplistic sonifications of values. Thus it is difficult to briefly summarize how these values are mapped in each synthesized sound. Instead of attempting to dissect a large amount of sonification code, a small example of one line of code is provided to give some idea of the techniques used to sonify the packet data.

Figure 2 depicts a snippet of code near the end of a packet capture sonfiying a synthesizer in SuperCollider. This code depicts a delay line that is processing an earlier synthesized audio signal. The input signal is being modified by two nested single pole band-pass filters. These filters' resonant frequencies are modulated by the geographic location of the peer that the packet of information is being transferred to or from. Thus the further west a peer is the more high frequencies in the first filter. This is fed into the second filter which filters out more low frequencies the further south the peer is located. The progress of the peer's download determines the delay time of the delay line. Peer progress ranges from 0.0 to 1.0, however here that value is being wrapped at a modulus of 0.5. Thus, as peer progress advances from 0.0 to 1.0, the delay time of the delay line will

```
BufDelayC.ar(
     LocalBuf(44100*0.5),
     OnePole.ar(
          OnePole.ar(
               synth,
               lat.linexp(-150,150,-0.99,0.99)
          ),
          lon.linexp(-150,150,-0.99,0.99)
     ),
     (nodeProg%0.5),
     0.75,
     synth*0.75
),
```

Figure 2. Packet capture sonification code in SuperCollider.

start at 0.0 seconds and reach a peak of 0.5 seconds at the mid point, then return to 0.0 and increase to another peak of 0.5 at the completion of the peer's download. Finally the original signal is summed with the delay line and fed into a feedback loop(not shown) to produce a recursively filtered echo effect.

This is one part of a much more complicated and interwoven whole, with each mapped parameter serving many purposes throughout the whole sound. This produces the desired effect: an intricate and constantly evolving sound with a wide array of variety to sonify the many different characteristics of the thousands of packets of pirated information that are transferred throughout the performance.

6.4 Pirated Music Playback

The final system manages the actual audio that is being pirated. This system is not so much mapping as it is resource collection. This system also addresses the real goal of pirating MP3's, which is to actually *listen* to them. Thus it seems technically and musically logical to provide a system for playing back these stolen sounds. By using the keyboard the performer may move a red rectangle between the MP3 progress bars. Pressing certain buttons will convert the selected MP3 into a WAV file and load it into SuperCollider. If the file is incompletely transferred, it creates a WAV file that skips missing audio data, providing a shorter audio file with sharp jump cuts. Then the system employs one of several playback synths that alter the audio in different manners. The goal with these synths is to playback the audio in heavily altered yet still somewhat recognizable fashion.

Figure 3 shows an example of SuperCollider code that plays back pirated audio data. This system uses Fast Fourier Transformation (FFT) processes initialized with very large buffer sizes. Using a spectral buffer playback system, this plays the audio data at 3% of its original speed while maintaining the same pitch. Next the audio's spectral data is squeezed into half the space it normally fills. A brick wall filter is placed upon the signal to discard most of the high spectrum and leave the low end data. The low frequency data is then spectrally enhanced, placing three new harmonics above each frequency in the spectrum. Lastly it is once again squeezed into half of the spectral field. This produces a rich and slowly evolving low end drone sound

```
bufnum2 = LocalBuf.new(1024*16, 1);
chain = PV_PlayBuf(bufnum2, recBuf,0.03, 0, 1);
chain = PV_BinShift(chain, 0.5);
chain = PV_BrickWall(chain,-0.95);
chain = PV_SpectralEnhance(chain,3,2,5);
chain = PV_BinShift(chain, 0.5);
```

Figure 3. Pirated MP3 playback code in SuperCollider.

that is heavily influenced by the bass drum and bass lines of a pirated song. It is thoroughly altered, however given familiarity with a song it is actually rather easy to detect a slow moving distorted version of the bass present in a song. While the other two systems are (more or less) tuned, this system consciously makes no effort to alter the tonality of the original song. A combination of these three distinct layers, the droning file transfer mapping, the percussive packet capture sounds, and the processed songs, produces a kaleidoscopic polytonal morass.

7. ARTISTIC CONSIDERATIONS

7.1 Non-linearity and Pseudo-linearity

The network data being mapped in *Leech* may be categorized by the manner in which it traverses its range. Pseudo-linear data moves in one direction, never skipping forward or backwards. This includes the overall download progress, progress for each individual torrented file, and number of peers that have connected to the system. This data is not strictly linear however, as the time span it takes to traverse the range of this data is not predetermined and differs for each performance and for each datum. Other data traverses its range non-linearly, skipping forward and backward at differing rates of speed. This includes download/upload rate, peer locations and peer download progress.

Having these two different types of data present is quite useful for creating a musical composition. Linear data allows the piece to have an overall form and shape, and to create a sense of tension, much like a normal non-realtime precomposed piece. *Leech* will always start off with quiet drones in the beginning, with the download progress at zero. As the piece advances, the download progress reaches closer to 100%, the drones increase in amplitude and complexity, creating a long build in tension. However, the non-linear data serves to provide variety in the piece. While pseudo-linear data tends to have an effect on the top most scale of the piece, being the form, the non-linear data provides unpredictable embellishment at the note scale. Download and upload rate are in constant flux, and each peer that a packet is transferred to will have a different and unpredictable geographic coordinate and download completion. These constant variations on a smaller time scale produce different tonal and timbral figures and patterns and add unpredictability from moment to moment. In combination these two forces give the system a sense of direction and life.

7.2 Transparency

Transparency in presenting the music being pirated is central to the piece. In compositions that focus on the concept of borrowed material, such as Luciano Berio's Sinfonia Mvt. 3, it can be at times difficult to identify exactly what is being borrowed and manipulated. *Leech* attempts to balance creative musical modification with transparency. Audio effects that maintain cognizable portions of the sonic material are purposefully employed.

One example of this is FFT based speed reduction, which create long evolving drones while maintaining identifiable pitch material. This audio transparency is accentuated by the use of visuals in the piece. The name of the artist, album, and each individual MP3 is clearly displayed in the visuals to inform the audience of exactly which material is being downloaded. Whenever a song is selected to be played back in modified form, it is hi-lighted on the screen to inform the audience exactly what song they are hearing being processed.

7.3 Collaboration

Collaboration is key to the mechanisms and compositional underpinnings of *Leech*. The process of illegally obtaining music is in fact a social and communal activity. Peer-to-peer networks such as BitTorrent require that a group of users proliferate information between each other in a mutually beneficial structure. The visuals in *Leech* attempt to demonstrate that the act of piracy brings together people from across the globe (though with less frequency in places such as Africa and China where free internet usage is restricted or unavailable). These peers are from many different cultures and societies, setting aside any differences to collaboratively share music.

The sounds themselves are also a collaboration. Two composers are involved in the artistic production of the piece, Curtis McKinney and Chad McKinney, twin brothers who have been collaborating for years on musical compositions. These composers also collaborate with the the artist's who's works are being sonically manipulated. Furthermore, the actual choice of what to pirate for performance of the piece is determined by popularity on the BitTorrent search engine `http://isohunt.com`. Using this selection process popular artists such as Rhianna and Lady Gaga have been used for the piece in recent past.

8. FUTURE WORK

Several new capabilities will be added to Leech in the coming future. As it stands the main interaction a performer has with the system is simply through starting and stopping the different pirated songs being downloaded. In the future more performative controls will be added to make performance more gratifying and emotive. These control will be primarily aimed at changing the manner in which the sonification occurs through a performance. One example of this would be to introduce a parameter that may alter the range of pitches that the location of a peer causes to occur. The capability to make changes such as this during performance would add more variety and musicality to the system.

Creating a version of *Leech* meant for presentation as an installation piece is also under review. This would involve streamlining setup, creating an auto-resetting capability, and changing the system so that participants are able to download whatever song they choose through a search prompt and keyboard.

Plans are under way for future pieces that utilize sonification of illicit network streams. A new piece entitled *Panopticon* is being constructed which will visualize and sonify a local area hacking technique known as arp poisoning. Using this method it is possible to monitor the network traffic of an entire local area network, peering into the private lives of individuals, and capturing private information. Viewing this private information in real time it is possible to see and hear what websites various users are browsing, what videos and music they are streaming, and any password or bank information they enter while on the network. This piece will serve to explore the ramifications of the dawning age of free information and loss of privacy that technology is thrusting upon us.

9. CONCLUSION

The overall goal of *Leech* is to produce a kaleidoscopic visual and sonic insight into what many in our society deem worthy enough to share and listen to, but not to buy. This instrument lays bare not only the hidden mechanisms that computers use to communicate, a fascinating display in itself, but also the often times contradictory relationships that our culture has with music, community, and commerce. Given the ubiquity of piracy it cannot be simply swept under the rug as a symptom of irresponsible individuals. In a typical performance of *Leech* approximately 200-400 individuals may be observed as being involved from the world over. The sounds that emanate from the piece are derivative of these individuals' choice to partake in a communal illegal activity, the mechanisms used to enable this choice, and the music that they have chosen to steal. It is the sound of piracy itself.

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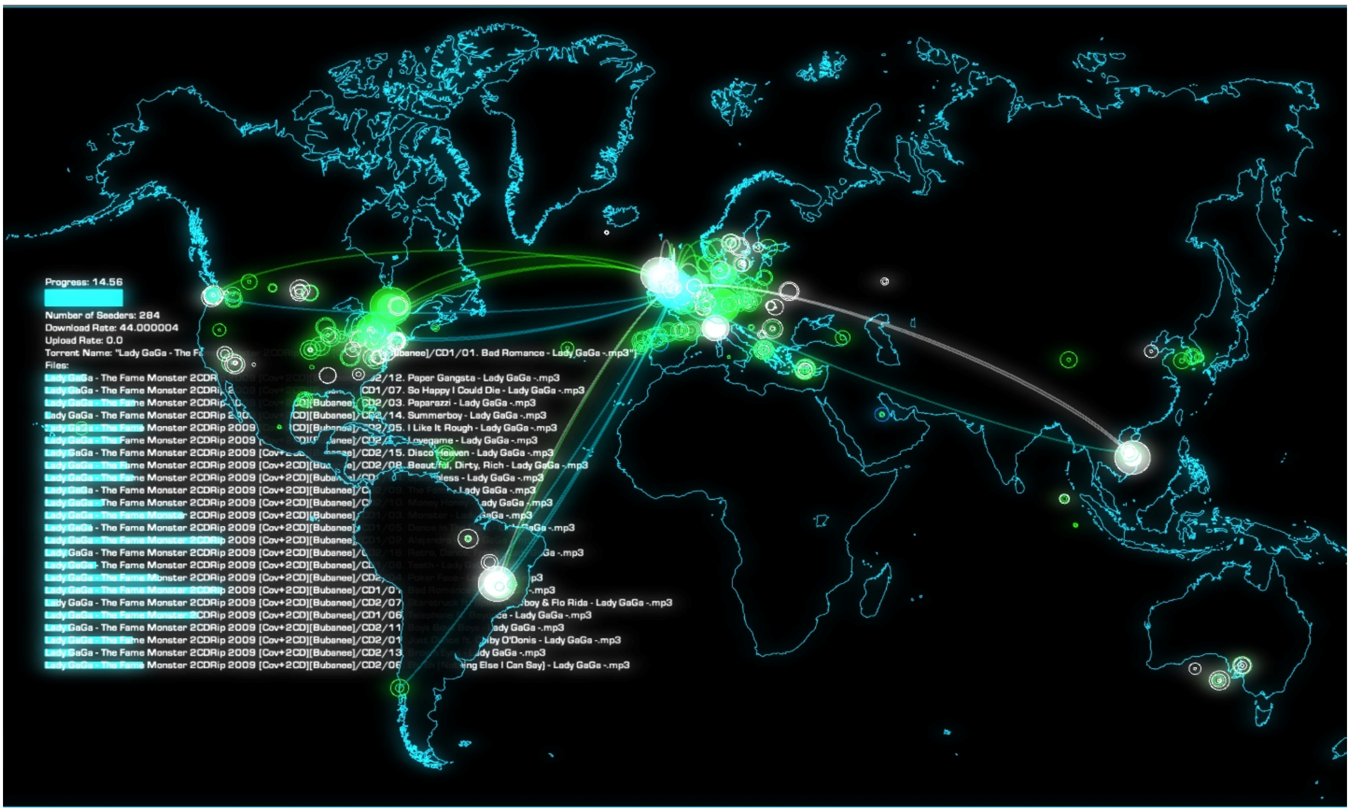
A. GRAPHICS EXAMPLE



Screen capture from a performance of *Leech*.