IMPLEMENTATION ISSUES IN THE DEVELOPMENT OF A REAL-TIME, WINDOWS-BASED SYSTEM TO STUDY SPATIAL HEARING

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Overview

- **What is SLAB?**
  - SLAB is a customizable real-time 3-D audio and virtual acoustic environment rendering system
  - SLAB is being developed as a tool to study spatial hearing

- **Talk Outline**
  - Design goals and requirements
  - Hardware and software environment
  - Signal flow
  - Software architecture
  - Results

Design Goals

- **Flexibility**
- **Extensibility**
- **Maintainability**
- **Short Development Cycle**

Design Requirements

- **Real-time Rendering**
  - Low latency - at most 50ms
  - Fast update rate - at least 60Hz

- **Image Room Model**
  - Minimum requirements
    - shoebox room
    - 1st order reflections
  - Future
    - arbitrary room geometry
    - higher order reflections
    - late reverberation

- **High-fidelity HRTF Filtering**
  - Direct path: 128 FIR taps
  - Reflections: 32 FIR taps

Why a Software Renderer?

- **Host CPU Performance**
  - Host CPUs are now capable of delivering the power of hardware DSPs
- **Object-Oriented Analysis and Design**
  - Flexibility, extensibility, maintainability, and a short development cycle are inherent qualities of object-oriented software development
- **Persistence**
  - Software-only solutions are less likely to fall prey to changing proprietary APIs and discontinued special-purpose hardware
- **Wide Developer Base**
  - There are more developer resources for operating system APIs than special-purpose hardware solutions

Why Windows/Intel?

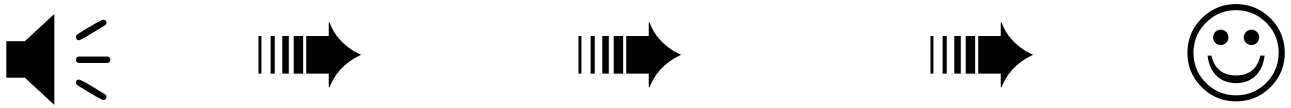
- **Physically Scalable**
  - Built upon readily available components
  - Easy to replicate SLAB systems

- **Affordable**
  - Complete 450MHz SLAB system costs roughly $1200.00
  - Anticipated 2GHz system, $3500.00

- **Emerging Technologies**
  - Low-latency sound (DirectSound, WDM)
  - Host CPU DSP instructions (MMX)
  - Multiple processor systems

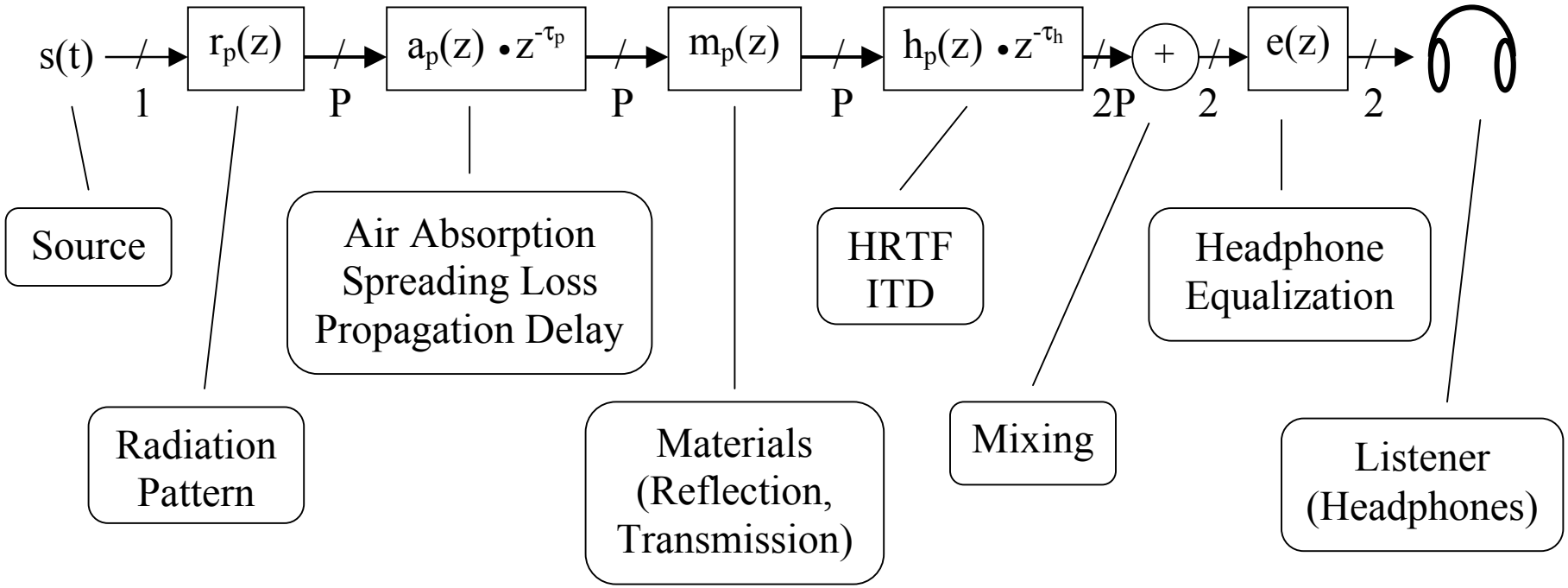
- **Current Lab Operating System**
  - Minimum modifications required for legacy experiment compatibility

Physical Scenario



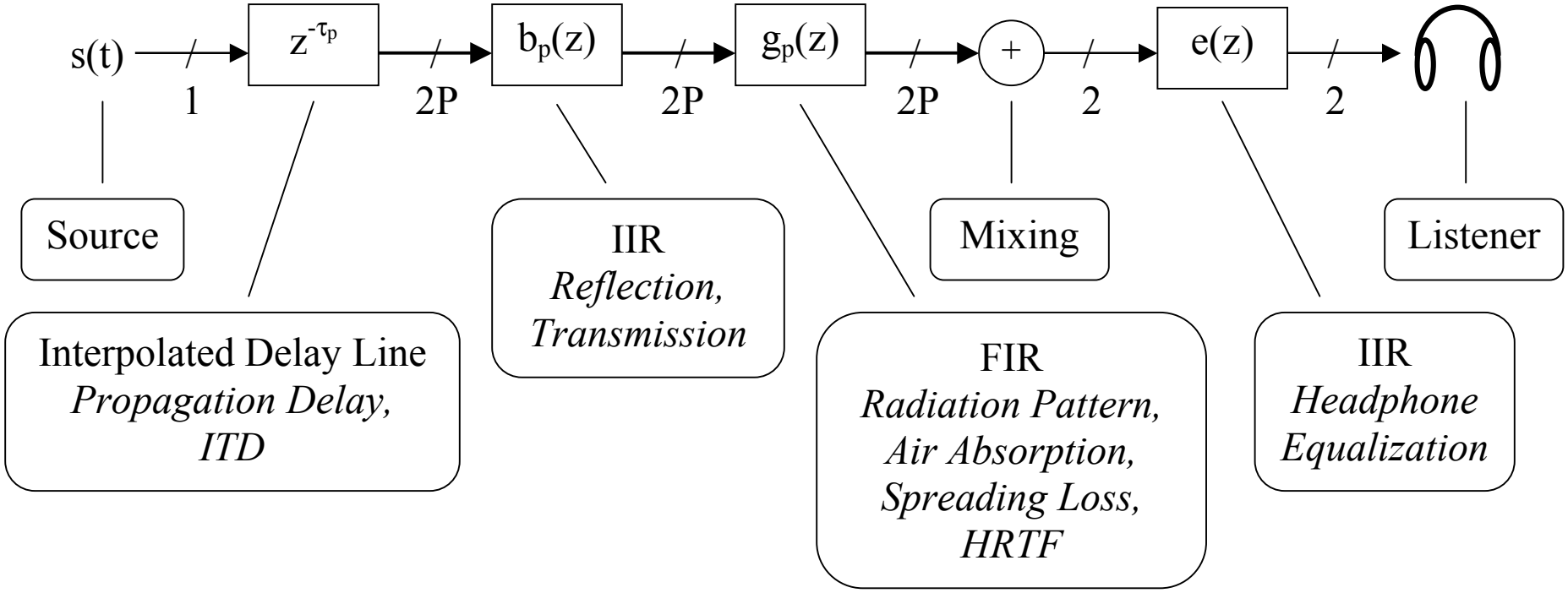
SOURCE	ENVIRONMENT	LISTENER
Location	Speed of Sound	Location
(Implied Velocity)	Spreading Loss	(Implied Velocity)
Orientation	Air Absorption	Orientation
Sound Pressure Level	Surface Locations	HRTF
Waveform	Surface Boundaries	ITD
Radiation Pattern	Surface Reflection	
Source Radius	Surface Transmission	
	Late Reverberation	

Physical Signal Flow



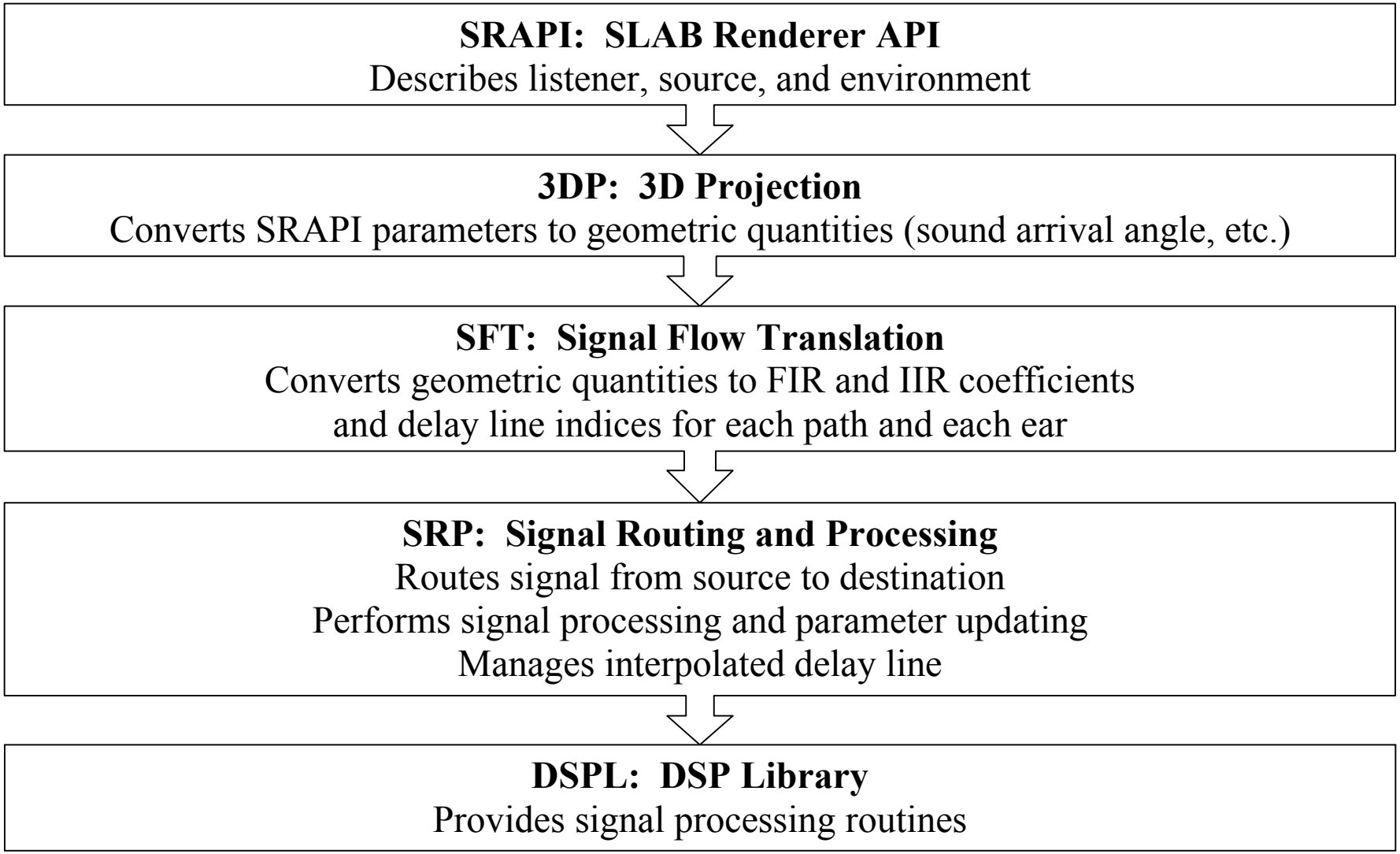
P = Number of Paths (Direct Path and Reflections)

SLAB Signal Flow
("Auralization Unit")

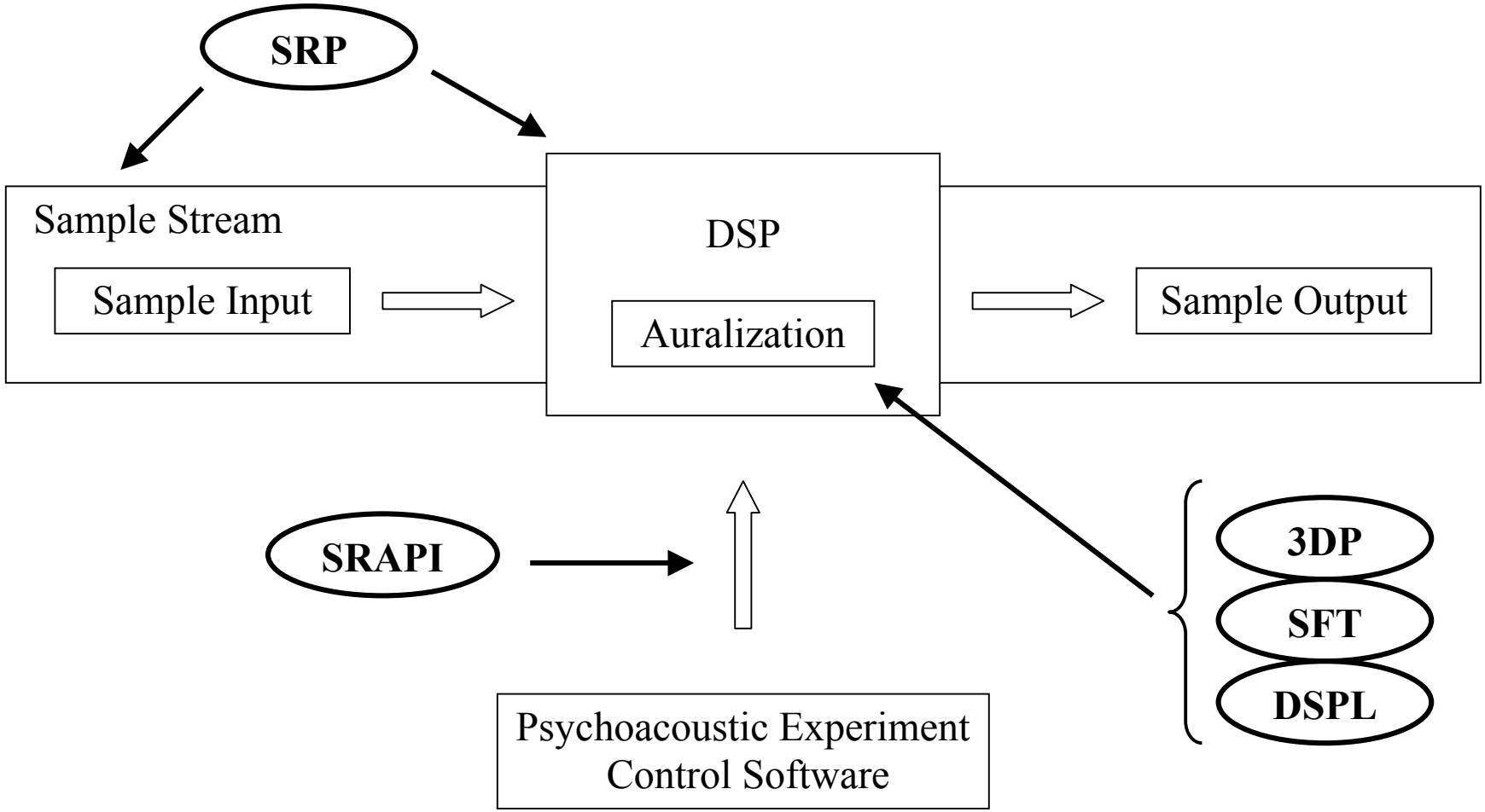


P = Number of Paths (Direct Path and Reflections)

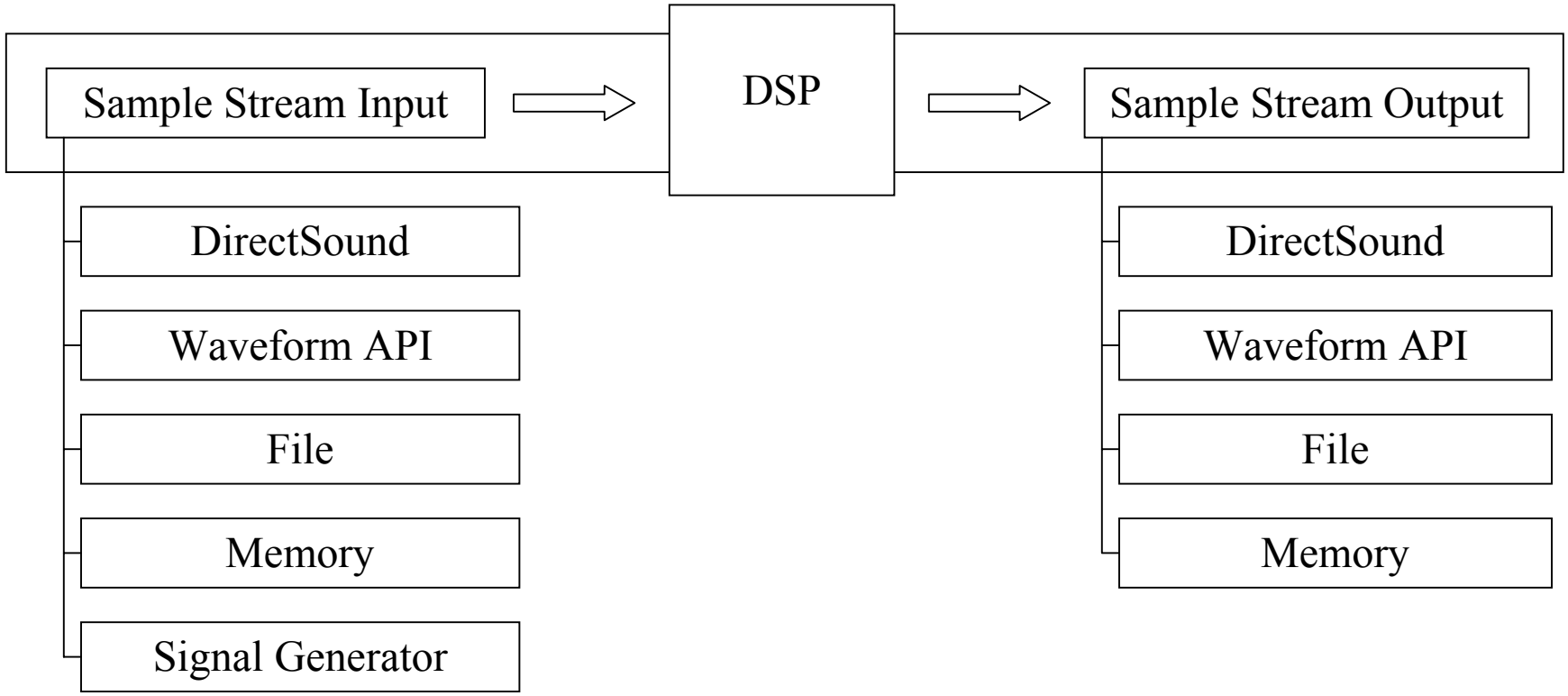
5 Conceptual Software Layers



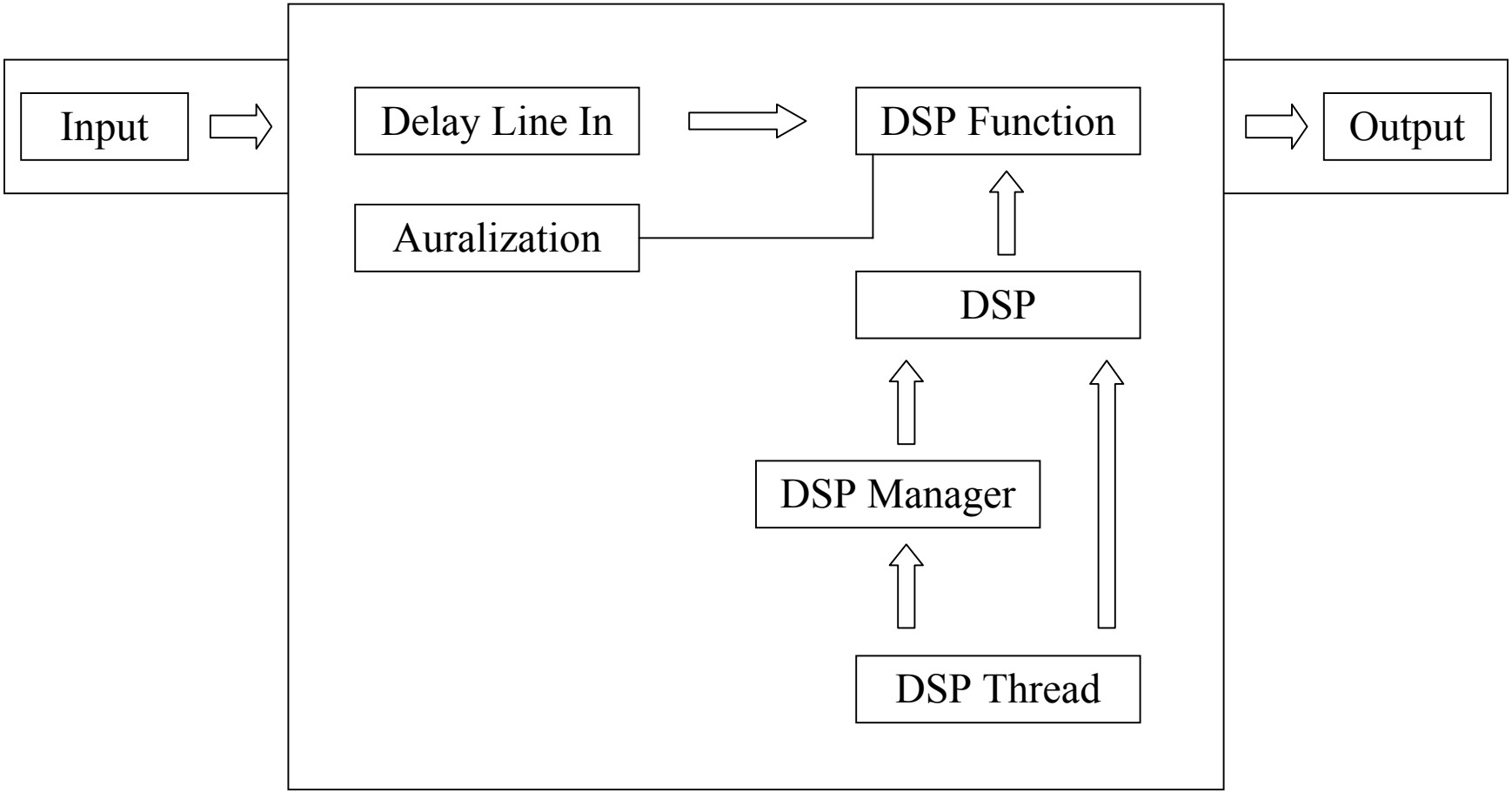
Software Architecture



Sample Stream Classes



DSP Classes


Input
Delay Line In
Auralization
DSP Function
DSP
DSP Manager
DSP Thread
Output

Tradeoffs and Hurdles

- **Audio API Tradeoff**
  - Waveform API (large latency) vs.
    DirectSound API (high CPU usage)

- **Operating System Tradeoff**
  - Windows NT (emulated DirectSound) vs.
    Windows 98 (single processor OS)

- **Windows Sound Card Drivers**
  - Undocumented “features”
  - Unreliable behavior

- **DirectSound Hardware Mixing**
  - Stream management overhead can cost more than software mixing

Current Specifications

- **Design Requirements**
  - Internal system latency: 48ms
  - Scenario update rate: 120Hz
  - Number of reflections: 6
  - Number of direct path FIR taps: 128
  - Number of reflection FIR taps: 32

- **System Dynamics**
  - Delay line smoothing: every sample
  - DSP coefficient smoothing: every 64 samples
  - Sample Rate: 44.1KHz

- **Computational Precision**
  - Sound data type: 16-bit integer
  - HRTF map data type: 16-bit integer
  - Environment data type: double precision floating point
  - DSP coefficients: floating point (16-bit integer MMX FIR)

The Future

- **Systems Issues**
  - Distributed system
  - Client-server architecture
  - Improved head tracker support
  - Full-duplex DirectSound audio
  - Digital I/O

- **Performance Issues**
  - Alternative low-latency audio options (WDM)
  - Performance tuning
  - Hand coded DSP algorithms
  - Windows 2000
  - Multiple processor systems