Input Slides 2024-12: My Two Slides

Daniel Topa
daniel.topa@hii.com

Huntington Ingalls Industries
Mission Technologies

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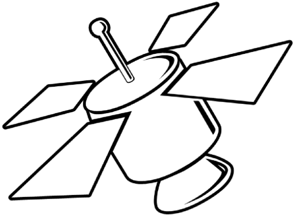
Models of Radar Cross Sections for Satellites



Spherical Harmonics Expansion

$$f(r,\theta,\phi) \approx a_{0,0}Y_0^0 + a_{1,-1}Y_1^{-1} + a_{1,0}Y_1^0 + a_{1,1}Y_1^1 + \dots$$

where

$$Y_n^m(\theta,\phi) = \sqrt{\frac{(2n+1)(n-m)!}{4\pi(n+m)!}}P_n^m(\cos\theta)e^{im\phi}$$

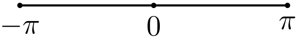
Overview

1. Writ Large
2. Software Components

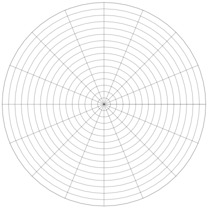
Goal: RCS Models in 3D

RCS models have been built in 2D.
Extend to 3D using the same MoM code.

Fourier Domains in 1-, 2-, and 3D

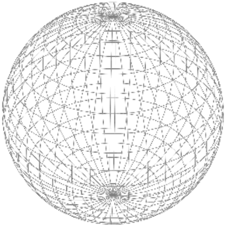


$$\theta \in [-\pi, \pi]$$



$$\theta \in [-\pi, \pi]$$

$$r \in [0, 1]$$



$$\theta \in [-\pi, \pi]$$

$$r \in [0, 1]$$

$$\phi \in [0, \pi]$$

Why We Love Fourier for Smooth Functions

Smooth Functions, Beautiful Representations

- **Weierstrass Approximation Theorem:** Any continuous function on $[a, b]$ can be uniformly approximated by polynomials. Fourier provides a similar approximation, using trigonometric bases instead of polynomials.
- **Riesz-Fischer Theorem:** Hunting license - Fourier coefficients $(a_n, b_n) \in l^2$, guaranteeing convergence in the L^2 sense.
- **Uniform Convergence for Smooth Periodic Functions:** Smooth (C^∞ or C^k) functions, Fourier series converge uniformly, ensuring no oscillatory artifacts (Gibbs phenomenon disappears).
- **Orthogonality of Basis:** Sines and cosines form an

Fourier and Extensions to 2- and 3D

1D:
$$f(\theta) = \sum_{n=-\infty}^{\infty} a_n e^{in\theta}$$

2D:
$$f(r,\theta) = \sum_{n=0}^{\infty} \sum_{m=-n}^{n,2} a_n^m R_n^m(r) e^{in\theta}$$

3D:
$$f(r,\theta,\phi) = \sum_{n=0}^{\infty} \sum_{m=-n}^{n} a_n^m \sqrt{\frac{(2m+1)(m-n)!}{4\pi(m+n)!}} P_l^m(\cos\theta) e^{in\theta}$$

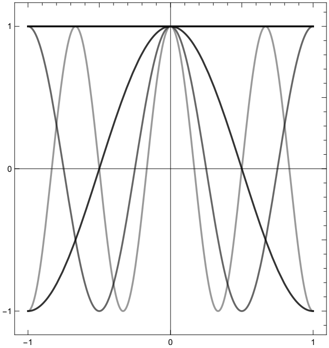
Fourier and Extensions to 2- and 3D

- **1D Fourier Series:** Decomposes a periodic function $f(\theta)$ into a sum of complex exponentials with coefficients a_n capturing the amplitudes of each frequency component.
- **2D Fourier-Bessel:** Extends Fourier analysis to two dimensions using radial functions $R_n^m(r)$, often employed in circular domains or optical applications.
- **3D Spherical Harmonics:** Represents functions on a sphere using harmonics $Y_l^m(\theta, \phi)$ and radial components $R_l(r)$, crucial in fields like quantum mechanics and gravitational modeling.

Lowest Order Fourier Basic Functions

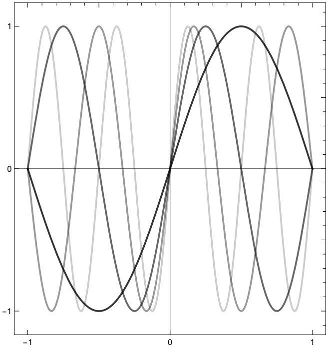
$$f(-\theta) = f(\theta)$$

Even Parity

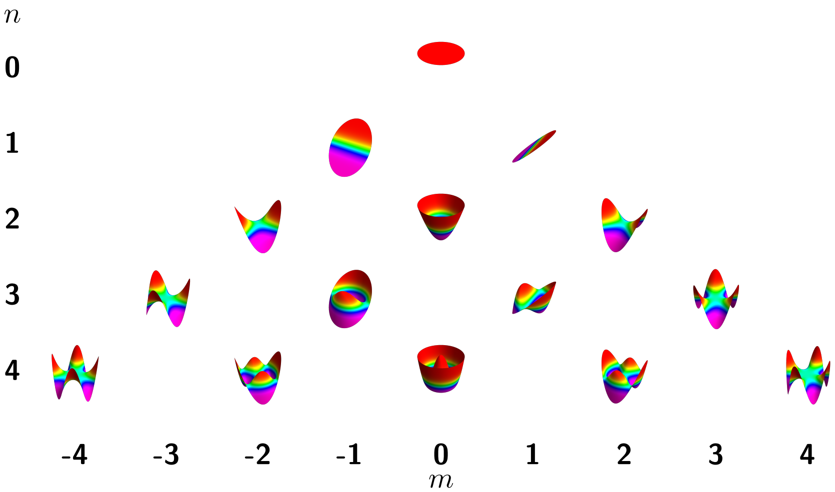


$$f(-\theta) = -f(\theta)$$

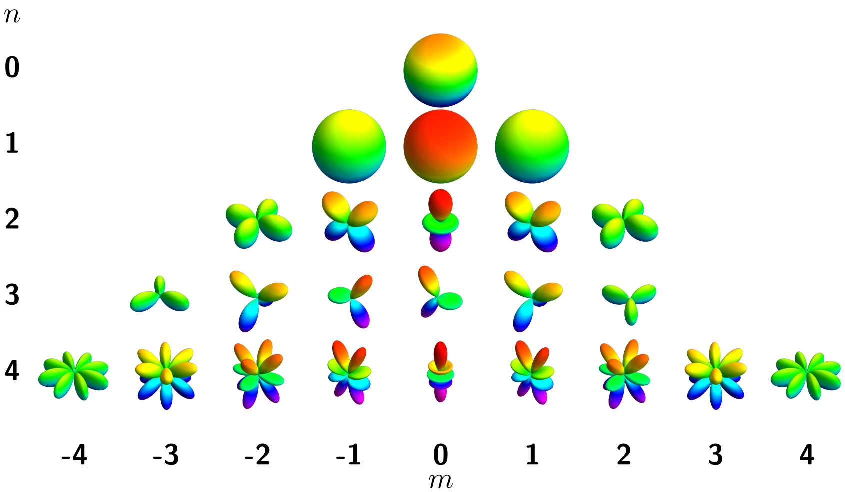
Odd Parity



Lowest Order Zernike Disk Polynomials



Lowest Order Spherical Harmonics



Code Conversion Overview

MATLAB and ALPINE Codes Converted

- **Python**
- **Fortran**
- **Shell Scripts**

Survey and Details Follow.

Primary Components

Fortran:

1. **toolkit 1**

Python:

1. **script 1**

Bibliography I

[1] Eugene F Knott, John F Schaeffer, and Michael T Tulley. Radar cross section. SciTech Publishing, 2004.

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[3] MIT Lincoln Lab. “Target Radar Cross Section”. In: Introduction to Radar Systems. MIT Lincoln Lab. MIT Lincoln Lab, 2002, p. 45. URL: https://www.ll.mit.edu/sites/default/files/outreach/doc/2018-07/lecture%204.pdf.

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[4] Peyton Z Peebles. Radar principles. John Wiley & Sons, 2007.

[5] Merrill I Skolnik. "Introduction to radar". In: Radar handbook 2 (1962), p. 21.

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