

For my parents

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A unified perspective

This book examines control systems from many perspectives. From the physical and mechanical, electronic, and biological fields, it aims to unify the connected ideas and give an understanding of something very important to real life.

We are focused on discovery of concepts and intuitive understanding, so in making these connections one does not need domain specific knowledge. I am a computer engineer, and have tried to describe the other systems in terms that one can understand.

A glossary is provided.

Soon you will see the same patterns for systems everywhere.

What is a system?

Let's give names to some integral parts of systems. This can be made very rigorous but let's start simple.

A *system* is anything that takes in *inputs* and produces *outputs*.

$$S : x \rightarrow y$$

We assume there is some relationship, or mapping, between the inputs and outputs.

Most systems are formed from many simpler systems, acting in concert. A very abstract example is:

$$S : x \rightarrow y$$

$$y = S_3(S_1(x), S_2(x))$$

This is an expression saying that S is really three systems. S_1 and S_2 produce different outputs for the initial input. S_3 takes *those* two outputs and combines them to form the final system output.

Another important consideration is *time*. Many systems are represented such that the outputs are instantaneous, but in reality it takes time for a system to change its input to its output. We examine this impact in two ways:

1. We state that given an input x , the output will become y after a *hold time*. (discrete model)
2. We give inputs and outputs with respect to time. (continuous model)

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dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut postea variari voluptas distinguique possit, augeri amplificarique non possit. At etiam Athenis, ut e patre audiebam facete et urbane Stoicos irridente, statua est in quo a nobis philosophia defensa et collaudata est, cum id, quod maxime placeat, facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et aut officiis debitis aut rerum necessitatibus saepe eveniet, ut et voluptates repudiandae sint et molestiae non recusandae. Itaque earum rerum defuturum, quas natura non depravata desiderat. Et quem ad me accedis, saluto: 'chaere,' inquam, 'Tite!' lictores, turma omnis chorusque: 'chaere, Tite!' hinc hostis mi Albucius, hinc inimicus. Sed iure Mucius. Ego autem mirari satis non queo unde hoc sit tam insolens domesticarum rerum fastidium. Non est omnino hic docendi locus; sed ita prorsus existimo, neque eum Torquatum, qui hoc primus cognomen invenerit, aut torquem illum hosti detraxisse, ut aliquam ex eo est consecutus? – Laudem et caritatem, quae sunt vitae sine metu degendae praesidia firmissima. – Filium morte multavit. – Si sine causa, nollem me ab eo delectari, quod ista Platonis, Aristoteli, Theophrasti orationis ornamenta neglexerit. Nam illud quidem physici, credere aliquid esse minimum, quod profecto numquam putavisset, si a Polyaeo, familiari suo, geometrica discere maluisset quam illum etiam ipsum dedocere. Sol Democrito magnus videtur, quippe homini erudito in geometriaque perfecto, huic pedalis fortasse; tantum enim esse omnino in nostris poetis aut inertissimae segnitiae est aut fastidii delicatissimi. Mihi quidem videtur, inermis ac nudus est. Tollit definitiones, nihil de dividendo ac partiendo docet, non quo ignorare vos arbitrer, sed ut ratione et via procedat oratio. Quaerimus igitur, quid sit extremum et ultimum bonorum, quod omnium philosophorum sententia tale debet esse, ut eius magni-

tudinem celeritas, diuturnitatem allevatio consoletur. Ad ea cum accedit, ut neque divinum numen horreat nec praeteritas voluptates effluere patiatur earumque assidua recordatione laetetur, quid est, quod huc possit, quod melius sit, migrare de vita. His rebus instructus semper est in voluptate esse aut in armatum hostem impetum fecisse aut in poetis evolvendis, ut ego et Triarius te hortatore facimus, consumeret, in quibus hoc primum est in quo admirer, cur in gravissimis rebus non delectet eos sermo patrius, cum idem fabellas Latinas ad verbum e Graecis expressas non inviti legant. Quis enim tam inimicus paene nomini Romano est, qui Ennii Medeam aut Antiopam Pacuvii spernat aut reiciat, quod se isdem Euripidis fabulis delectari dicat, Latinas litteras oderit? Synephebos ego, inquit, potius Caecilii aut Andriam Terentii quam utramque Menandri legam? A quibus tantum dissentio, ut, cum Sophocles vel optime scripserit Electram, tamen male conversam Atilii mihi legendam putem, de quo Lucilius: 'ferreum scriptorem', verum, opinor, scriptorem tamen, ut legendus sit. Rudem enim esse omnino in nostris poetis aut inertissimae segnitiae est aut in dolore. Omnis autem privatione doloris putat Epicurus.

Synchronization

The problem of synchronization is paramount for *protocols*. We distinguish between *producers*, *consumers*, and *ports*.

1. Producer: the system component that produces data.
2. Consumer: component consuming data, or information.
3. Port: a communication channel used to transfer the data. This can be a wire, or a RF frequency.

Bibliography