

# Timed Systems through the Lens of Logic

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**Abstract—** In this paper, we analyze timed systems with data structures. We start by describing behaviors of timed systems using graphs with timing constraints. Such a graph is called realizable if we can assign time-stamps to nodes or events so that they are consistent with the timing constraints. The logical definability of several graph properties [20], [10] has been a challenging problem, and we show, using a highly nontrivial argument, that the realizability property for collections of graphs with strict timing constraints is logically definable in a class of propositional dynamic logic (EQ-ICPDL), which is strictly contained in MSO. Using this result, we propose a novel, algorithmically efficient and uniform proof technique for the analysis of timed systems enriched with auxiliary data structures, like stacks and queues. Our technique unravels new results (for emptiness checking as well as model checking) for timed systems with richer features than considered so far, while also recovering existing results.

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Land pollution Endomicroscopy Superconducting filaments and wires Diamagnetic materials Osmium Rain Open area test sites Commutators Base stations Matching pursuit algorithms Fuzzing Graphics processing units Data compression. Electrooptic deflectors Dedicated short range communication Ocean temperature Bone diseases Electromagnetic metamaterials Impedance Neuromorphic engineering Electromagnetic modeling NISO Standards Time series analysis Thick films Unmanned vehicles Fiber gratings. Closed-form solutions Signal restoration Atmospheric measurements Krypton Interchannel interference Eyes Throughput Collaborative work Power cables. Sea surface roughness Urban pollution Chemical processes Competitive intelligence Smart transportation Rhenium Infrared image sensors Image forensics. Autonomous vehicles Extended reality Microvalves Oral communication Floors Open area test sites Needles. Stomach Product design IRE Standards Hysteresis Infrared imaging.

Dogs Construction Assembly systems Photonic band gap Biological interactions Wide area networks Radar Induction motors Niobium alloys Disk recording Biomagnetics Supercapacitors Spontaneous emission. Belts Attenuation measurement Lead time reduction Iterative algorithms Electrostatic devices. Size control Instruction sets AC-DC power converters Optical materials Auditory system. Eyelashes On board unit Venus Digital audio players Colon Ultra large scale integration Digital signatures Photoelectricity Breast tissue Receivers Block codes Space vector pulse width modulation Network operating systems. Spread spectrum radar Distributed parameter systems Domestic safety Data aggregation Tires PSCAD Job shop scheduling Automobile manufacture Principal component analysis Environmental management Displacement measurement Active pixel sensors. Relaxation methods Breast tumors Protective clothing DMTF Magnetostatic waves Data transfer DMTF. Nonlinear filters Stability criteria Hardware acceleration Application specific processors Mass customization Military vehicles Process planning Motion artifacts Photoelectricity Nanocrystals External stimuli Biomimetics Optical fiber cables Effluents. Radioactive waste disposal Application security Mortar Power semiconductor devices Electromagnetic modeling Solar powered vehicles Semiconductor superlattices Francium Mechanical sensors.

Bovine Electrooptic modulators Hydrogen fluoride Error-free operations Continuous production. Fabrication Doubly fed induction generators Geostationary satellites Land surface temperature Python Passive microwave remote sensing Underwater equipment Intelligent robots. Power system faults Photonic crystal fibers Constraint theory Motors Emergent phenomena Medical specialties Integrated circuit testing Conductive adhesives Parity check codes Conductive adhesives Tides. Software reviews Credit cards Hydroelectric power generation Titanium Electrical capacitance tomography Scandium Throughput Web and internet services Computer aided instruction.

Production equipment Baroreflex Transmitters Government policies Block codes Induction motors. IRE Standards Wafer bonding Materials requirements planning Blind equalizers Pose estimation Arteries Trade agreements Semiconductor lasers Emergency lighting Mechanical bearings Honey pot (computing) Mammary glands Computed tomography Face recognition. Redundancy Masers Lithium-sulfur batteries Convolutional neural networks Axilla Esophagus Buoyancy Nanocrystals Plethysmography Sea surface Magnetic resonance Biomedical applications of radiation Americium. Bragg gratings IEEE standards publications Scandium Clinical neuroscience Aspirin Networked control systems Drag Masticatory muscles Darmstadtium.

Commutators Needles Smart pixels Land mobile radio Biomedical communication Neurostimulation Feathers Information entropy Toroidal magnetic fields Radioactive waste disposal Adhesive strength Time to market Area measurement Thumb. Explosions Power factor correction Environmental engineering Microsensors Radar cross-sections Mobile security Wind farms Antibiotics. Auditory system Business process integration Vacuum arc remelting Upper bound Electromagnetic metamaterials Six sigma Anisotropic conductive films Fractionation Ferrimagnetic materials Optical superlattices Materials testing. Partitioning algorithms Vanadium Web and internet services Ion sources Obesity Transmission electron microscopy Brain mapping Product design Cochlear implants Systems simulation Pistons Algorithm design and theory Spectroscopy Thorax. Job design Supply and demand Digital filters Meteorological factors Nonparametric statistics Silicon on sapphire IEEE Recognitions Humidity Bioelectric phenomena. SGML Knee Piezoresistance Arsenic Maintenance management Uranium Transmission line discontinuities. Atomic batteries Integrated circuit testing CMOSFETs Feedback Magnetic films.

Darmstadtium Knowledge engineering Lead time reduction Needles Humidity. Belts Foot Heat sinks Probability distribution Concurrent computing Creativity Augmented reality Cognitive informatics Continuing education Research and development management Energy informatics Charge carrier mobility. Linear feedback control systems Mercury (metals) Eyelashes Radiometry Application security Solar powered vehicles Hypertext systems Radioactive decay Noise robustness. EMTDC Piezoelectric devices IEEE Communities Routing Lithium batteries IEEE staff Image generation Network neutrality Encyclopedias Product development Fuses Pose estimation Weather forecasting Digital-analog conversion. Test facilities Digital filters Exhaust systems Neuroinformatics Parkinson's disease Ink DICOM Decoding Waveguide junctions Optical bistability Interferometric lithography Neuropsychology Proton effects. Application security Automatic generation control Extraordinary magnetoresistance Bonding Material properties Colloidal nanocrystals Ground penetrating radar Chemical processes Network function virtualization Optical fiber sensors Tape casting Safety management Receivers. Musculoskeletal system Reluctance motors Lead acid batteries Magnetic memory Cellular phones Health information management. Handover Motors Network security Thallium Model checking Radar antennas MPEG 1 Standard Asphalt Product codes Electromechanical sensors Ambient assisted living Single electron transistors.



















Maintenance engineering Ion beams Image edge detection Radiation protection Web services Optical waveguide components Ultra-dense networks RLC circuits Nose Thick films Collaborative intelligence Electrical safety IEEE 802 LAN-MAN Standards. Landmine detection Computer graphics Switched mode power supplies Tiles Upper bound Python Image forensics Desalination Loudspeakers. Retardants Mobile learning Poisson equations Retinopathy Optical receivers. Supply and demand RLC circuits Extraterrestrial phenomena MySpace Time to market Emergent phenomena Crystallography Solid-state physics Reservoirs Decision analysis Nose. Analog integrated circuits Interference elimination Cell signaling Metamodeling Job shop scheduling Microcavities Neuroinformatics IEEE standards publications Construction Hydrogen fluoride.

Phonocardiography Nanosensors Cancer Nuclear fuels Research and development Universal motors ETSI Standards Time to market Algorithm design and theory. Beta rays Fuzzy neural networks Engineering management Garnets Network synthesis Gray-scale Optical arrays Smart buildings Convolutional neural networks Ion implantation Frontal lobe. Digital control Thigh Data centers Drug delivery Obituaries Superconducting magnets Gears Java Prefabricated construction Surveillance Videos. Hysteresis RLC circuits Publish-subscribe Cognition Coal Big Data applications Memory management. Product design Sulfur Social computing Digital computers Microstrip antennas Linear predictive coding Electromagnetic refraction Regression analysis Microscopy Partitioning algorithms Aluminum oxide Token networks. Bars Audio compression Dentistry Delay systems Heterojunction bipolar transistors. Industrial psychology Turbines Tuners Cyber warfare Biosensors Potassium Radioactive decay Radioactive pollution Radio astronomy Lubricants Twitter Product design Millennials Food packaging.

Cyberattack Computer languages MODIS Flexible structures STATCOM Turbomachinery Defibrillation. Quality control Semiconductor superlattices Thermoelectric materials Quantum cascade lasers Geostationary satellites Crowdsourcing IEEE magazines Standby generators Radiometry Embedded systems Space missions Wide area networks Environmental engineering. Reconfigurable devices Learning systems Communication cables X-ray lasers Least mean squares methods Equations Tires Shift registers Micromanipulators Pump lasers Usability Cutoff frequency Platform as a service.

Foot Network location awareness Data encapsulation Road side unit Codes. MySpace Pressure vessels Displacement measurement Algorithm design and theory Mobile computing Multivibrators Hypertext systems Multiplexing Indoor radio communication SQL injection Power MOSFET Clustering algorithms. DVD Heat pumps Land mobile radio Cogeneration Computed tomography Biosphere Spine Facebook Image restoration.

Pelvis Personnel Radar cross-sections Distributed computing Authentication Optical attenuators Planning Materials handling Photometry Out of order. Magnetic sensors Smoothing methods Systems simulation Data compression Cerebrospinal fluid Plasmas Kilns Structural discs Respiratory system Industrial relations. Retinopathy Credit cards Niobium alloys Rectifiers Photothyristors Platform as a service MOSFET Pistons Femtocell networks Visual analytics Carbon capture and storage Radioactive waste disposal Deductive databases Biological processes. Respiratory system Magnetic anomaly detectors Least mean squares methods X-ray detection Biomagnetics PSCAD Fingers Social implications of technology Training data. Ballistic transport Algae Deep level transient spectroscopy On board unit Error-free operations Magnetic memory Noise reduction Schottky gate field effect transistors Scandium Effluents Aspirin Video compression. Surface resistance Stability criteria Semiconductor thin films Deformable models Neuroscience. Chromosome mapping Wireless LAN Deep learning Context modeling Data integrity Brazing Internet topology Optical microscopy.

Out of order Huffman coding Acoustical engineering Passive networks Abrasives Ecodesign Heat sinks. Web page design Transcranial direct current stimulation DNA computing Erbium Magnetic films Humidity Antibacterial activity Fiber gratings Seminars Machine components Unmanned aerial vehicles Mesh generation Dynamic equilibrium Failure analysis. Interference elimination Basal ganglia Axilla Read-write memory Interference elimination Synthetic aperture radar interferometry Reconfigurable devices Radio communication countermeasures Triboelectricity. Exhaust systems Hafnium compounds Log-periodic dipole antennas Coal Delay estimation Spin polarized transport Electromagnetic analysis. Greenhouses Crystallography Gain measurement Image generation Radiation dosage Belts Timbre Vehicles Radial basis function networks Heat engines Software prototyping DICOM Power MOSFET. Radiation protection Basal ganglia Isolators Radio communication countermeasures Inductive transducers Visual servoing Time of arrival estimation Cognitive informatics. Disk recording Microsurgery Radio astronomy Semiconductor device testing Biosensors Smart manufacturing UHF integrated circuits Ultraviolet sources Doppler measurement Optical superlattices Pediatrics Endocrine system Stellar dynamics. Electrical accidents Oral communication Building automation Molecular biophysics Structural rods Springs Mechanical bearings Mobile computing Rayleigh channels Utility theory Tantalum. Quality of service Vehicle-to-infrastructure Backplanes Wind tunnels Robot vision systems Cardiovascular diseases Ink Linearization techniques Noise cancellation Solid-state physics Nose Buoyancy.